HANDBOOK of Training in Mine Rescue and Recovery Operation 1978

ISSUED BY THE
MINISTRY OF LABOUR

HANDBOOK
OF
TRAINING IN MINE RESCUE AND RECOVERY OPERATIONS

Prepared, published and issued by the Mining Health and Safety Branch of the Ontario Ministry of Labour for the use of men training in Mine Rescue and Recovery operations at the Mine Rescue Stations established in the Province.

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In equipping the rescue stations established in Ontario and in training men in the use of equipment, the standards adopted by the United States Bureau of Mines have been closely followed. Grateful acknowledgement is made for the permission of the Bureau to use the information contained in its many publications relating to mine rescue and recovery operations following fires in mines. In preparing this handbook the text in these publications has been freely copied.

Much assistance has been rendered by the manufacturers of breathing apparatus and other equipment used in Mine Rescue Training.

Suggestions by a special Fire Committee set up by the Mining Industry of Ontario to investigate fire-fighting operations are gratefully acknowledged and deeply appreciated.

PREFACE

Purpose

The purpose of this Handbook of Training in Mine Rescue and Recovery Operations is to provide a guide for the training of the personnel constituting mine rescue teams in the knowledge, care and use of apparatus for protection in irrespirable atmospheres, the detection of noxious gases and a general knowledge of accepted procedures to be adopted during rescue and recovery operations during or following a mine fire. It is meant to serve as a reference guide for the members of mine rescue teams.

History

Training in mine rescue and recovery operations by the Ontario Government was inaugurated in the Province of Ontario in 1929. The first Government Mine Rescue Station was established in Timmins in that year. Since that time six more stations have been established and training has been made available in all the active mining districts of the province. The following table shows the names and addresses of the stations and the staffs employed:—

Name	Address	Staff
Red Lake Mine Rescue Station..	Red Lake.....	Superintendent.
Thunder Bay Mine Rescue Station	Thunder Bay..	Superintendent.
Sudbury Mine Rescue Station...	Sudbury......	Superintendents and Technician.
Onaping Mine Rescue Station...	Onaping.......	Superintendent.
Kirkland Lake Mine Rescue Station......................	Kirkland Lake.	Superintendent.
Porcupine Mine Rescue Station..	Schumacher ...	Superintendent.
Elliot Lake Dist. M.R.S.	Elliot Lake....	Superintendent.

Authorization

The authority for the organization and financing of the Mine Rescue Stations and the assignment of responsibilities are contained in the Mining Act, which reads as follows:—

—(1) Mine rescue stations shall be established, equipped, operated and maintained at such places and in such manner as the Minister may direct.

(2) The Lieutenant-Governor in Council may appoint such mine rescue officers as may be deemed advisable.

(3) The equipment and operation of mine rescue stations shall be in charge of such mine rescue officers and it shall be the duty of such officers to teach and train mine rescue crews and supervisors in the use and maintenance of the apparatus in such manner as the Director, Mines Engineering Branch may require, to maintain the apparatus in efficient and workable condition so as to be available for immediate use, and to perform such other duties as the Director may deem necessary.

(4) The owner, agent or manager of a mine shall cause such workmen and supervisors to be trained in the use and maintenance of mine rescue equipment as the Regional Engineer may deem necessary.

(5) The mine manager shall be responsible for the supervision and direction of mine rescue crews in all mine rescue and recovery operations conducted at the mine.

(6) The cost of establishing, maintaining and operating mine rescue stations shall be paid out of the Consolidated Revenue Fund.

(7) The Workmen's Compensation Board shall at the end of each quarter year reimburse the Consolidated Revenue Fund from moneys assessed and levied by the Board against employers in the mining industry for the total amount certified by the Deputy Minister to have been paid out under sub-section 6.

(8) All moneys received from the sale or disposal of any equipment, buildings or machinery forming part of or appertaining to mine rescue stations shall be paid to the Workmen's Compensation Board and shall be placed to the credit of the class funds of the employers in the mining industry.

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MINE RESCUE AND RECOVERY OPERATIONS

CHAPTER I

Selection of Rescue Team Personnel

Selection for Examination

The successful selection of suitable men for work in mine rescue and recovery operations depends on the judgment of the mine management, the examining physician and the Mine Rescue Station Superintendent.

Examination for Medical Qualifications

In order to be certain that only men sound of body, normal in mind and physically fit are selected for training in the use of self-contained oxygen breathing-apparatus, they should be examined by a physician and certified to be in proper physical and mental condition before training is begun, and at yearly intervals thereafter if they remain in active training.

The medical qualifications are set out in Chapter IX, together with the record forms for these qualifications and rescue-training status.

Assurance of Qualifications for Duties

The Mine Rescue Station Superintendent should assure himself that a man has possibilities of developing into a qualified member of a mine rescue team before training is begun.

To qualify as a member of a standard mine rescue team a man should have successfully completed the courses of training outlined in Chapter II. Physical and mental qualifications are very important. A new member of a rescue team should be—

(1) not younger than 21 years of age, nor over 45;

(2) organically sound, in good health, and physically fit;

(3) of temperate habits;

(4) of sound mind;

(5) clean shaven, with no moustache or beard to interfere with the facepiece of the apparatus worn;

(6) possessed of good vision and hearing;

(7) calm and self-controlled in emergency and danger;

(8) courageous, and have good judgment and initiative;

(9) strong and capable of performing long and arduous physical labour;

(10) familiar with underground mining conditions and practice;

(11) conversant with the practices of First Aid;

(12) able to speak, read and write English.

CHAPTER II

Training Courses

General Setup of Courses

Formal training in mine rescue and recovery operations consists of five courses. The first three are for the regular mine rescue teams, and the fourth and fifth are for mine supervisory staffs and management. Additional special refresher courses are given as needed to maintain efficiency.

CHART OF TRAINING COURSES, TRAINING PERSONNEL, CERTIFICATES AND SEALS

Training Course	Personnel Trained	Certificate
(1) Basic Training	Supervisors, Rescue teams	Division of Mines Basic Certificate
(2) (a) Standard Training (b) Modified Standard Training	Rescue teams Supervisors	Red Seal to be affixed to Certificate
(3) Advanced Training	Rescue teams	Gold Seal to be affixed to Certificate
(4) Supervisory Staff Training	Supervisors	Gold Supervisory Seal to be affixed to Certificate
(5) Managenent Course	Senior Mine Supervision	
(6) Refresher Course	All personnel	Record kept

Each course must be completed and an examination (written and practical) passed before the next course is

taken. Upon the completion of the Basic Course a certificate will be issued to the successful candidate. (Fig. 1). Seals to be affixed to the certificate will be issued upon the successful completion of each of the Standard, Advanced and Supervisory Staff Training Courses. (Figs. 2, 3 and 4).

The training schedules for these courses are outlined in this Chapter. The schedules may be modified to suit local conditions, but the efficiency of the training should not be allowed to suffer. The total training time to complete all courses should under ordinary circumstances approximate twelve 8-hour periods, or 96 hours.

Basic Training

The estimated total training time required for this course is 24 hours. It consists mainly of lectures with some practice.


CERTIFICATE NUMBER

ONTARIO

STANDARD MINE RESCUE TRAINING ONTARIO 19

ADVANCED MINE RESCUE TRAINING ONTARIO 19

Ontario Department of Mines

Basic
Certificate of Mine Rescue Training

This is to Certify *that* ______________ *of* ______________, *Ontario*

has been trained in the use of MINE RESCUE APPARATUS, *at the* ______________ *Rescue Station. During the training he performed hard labor in noxious and irrespirable gases and gave evidence of being qualified to care for and use rescue apparatus.*

Trained under the direction of *Approved* ______________ CHIEF INSPECTOR OF MINES

______________ SUPT. OF RESCUE STATION *Toronto, Ont.,* ______________ *19*......

Persons holding this certificate should undergo additional training every six months to keep in proper condition of efficiency.

Fig. 1.—Basic Certificate, showing Seals Attached.

Basic training is the foundation course for all mine rescue training. It is essential that all rescue men acquire a knowledge of the following:—

(1) The objects of rescue and recovery work following mine fires.

(2) The constituents and properties of normal air and gases which may be encountered in abnormal circumstances in mines.

(3) Methods of detection of these gases.

(4) Methods of protection of persons travelling in atmospheres contaminated by toxic or noxious gases.

(5) A preliminary training period in the actual wearing of the protective devices.

At the end of the Basic Training Course an examination will be held on the work covered. A successful candidate will be granted a Division of Mines Certificate of Basic Mine Rescue Training. The examination will be set by the Mine Rescue Station Superintendent or other person authorized by the Director.

Classes may be held for periods of approximately 4-hour or 8-hour duration. Eight-hour periods have been found to give the most satisfactory results. The outline of the course has been given for 4-hour periods in case this is necessary.

First Day.—Approximately 4 hours.

1. Enrolment of class and securing of data on class members.

2. Lecture.

An outline of the Objects of Mine Rescue and Recovery Work.

Air and variations of mine air from normal.

Various gases found in mine air and their effects on persons.

Treatment for gas poisoning.

Methods of detection of various gases found in mines.

Methods of protection against toxic or noxious gases; personal protection when testing for gas; gas masks and other breathing-apparatus.

3. Question Period

During this period the class will be expected to answer questions on the subjects covered in the lecture and should be urged to ask questions.

Second Day.—Approximately 4 hours.

1. Question period on previous work covered.

2. Lecture.

Types of protective equipment and their use.

The Type N Mask.

Wearing Type N Mask; practice in putting on and adjusting facepiece and harness; replacement and disposal of canisters; sterilizing facepieces.

Wearing Type N Mark while doing heavy work; precautions when using Type N Mask.

Oxy SR 45, its use and limitations.

Flame Safety Lamp, cleaning, filling, use and maintenance.

3. Question period.

Third Day.—Approximately 4 hours.

1. Question period on previous work covered.

2. Lecture.

Self-contained oxygen breathing-apparatus—Drager BG 174.

The principal parts of the apparatus and their functions.

The valves, their location, purpose and action.

The absorbent used and its functions.

The high-pressure gauge.

Demonstration of the principal parts.

3. Field Tests.

A. Demonstration, step by step of the four field tests necessary before wearing the apparatus. (a) pre-flush, bottle pressure and by-pass. (b) regenerator, (c) negative pressure, (d) facepiece.

B. Explanation of Universal Tester Model Rz 22, Rz 25 and Rz 35 as used in the testing of the Drager apparatus. Leaks in apparatus and how to locate them.

4. Practice with an apparatus for every man.

Step by step instruction in field tests; wearing and adjusting the apparatus to the wearer's comfort.

Walking as a team while under oxygen.

The necessity of team discipline.

Take off apparatus, remove oxygen bottles, empty regenerators, replace used bottle with spare one, sterilize apparatus.

Fourth Day.—Approximately 4 hours.

1. Question period on previous work.

2. Lecture—Methods of charging breathing-apparatus bottles.

How to connect large cylinders and the reason for using cylinders of different pressures.

How to fill apparatus bottles from large cylinders by equalization.

Testing breathing-apparatus oxygen bottles.

Team members should each fill and test at least one apparatus bottle.

3. Lecture

Methods of communication between rescue team and fresh air base.

Practise, with the members of the class "under oxygen" and in teams, going through a telephone drill, using signals as described in the lecture. Travel at least 600 feet under-

ground over a crooked route and return, while practising signals.

Practise all signals and methods of communication.

Fifth Day.—Approximately 4 hours.

1. Practical drill in light smoke.

Arrangements should be made for the use of a suitable drift or crosscut where smoke can be used without causing any interference with the mine ventilation. A training-tunnel, if available, may be substituted for this purpose.

(a) The following drill should be carried out before the travelway is filled with smoke.

The first team, equipped with Drager apparatus, should get "under oxygen" at the fresh air base with a stand-by team, if available, in attendance. The stand-by team should be equipped with Drager apparatus but should not get "under oxygen" until required. The first team should advance from the fresh air base and practise the use of the telephone in co-operation with the stand-by team, as would be required in an emergency.

Practise carrying an injured team mate.

Practise the use of the by-pass valve in emergency.

Practise the method of resuscitation by means of the by-pass valve.

Practise methods of marking the route of travel.

Return to the fresh air base and recharge apparatus.

(b) The following drill should be carried out in smoke.

With team "under oxygen" again advance from the fresh air base and repeat the drill outlined above.

Demonstrate the advantage of carrying the lights in the hand rather than on the hat.

Practise travelling as a team through smoke with lights turned off.

2. Return to lecture room.

Empty regenerators; recharge oxygen bottles, test and replace them in apparatus; sterilize apparatus.

Sixth Day.—Approximately 4 hours.

Examination

The examination may be conducted at the Rescue Station or other convenient place. It consists of two parts, practical and written.

The practical examination covers the wearing of the Type N and other masks, the Drager apparatus, and the use of various detectors.

The written examination covers the subjects taught during the course.

Standard Training

The estimated training time required for this course is 24 hours. Classes may be conducted in 4-hour or 8-hour periods. Standard Training may be given over three consecutive days of intensive training, or may cover a period of one year, with six training days.

Standard Training in Mine Rescue and Recovery Operations is a continuation of Basic Training. The course consists mainly of training in the wearing of the breathing-apparatus in irrespirable atmospheres and further instruction and practice in the problems that arise in mine rescue operations, such as team work, establishing a fresh air base, building various types of barricades, travelling in smoke, testing for gases, and other related matters.

At the completion of this course an examination will be given, and successful candidates will be granted the red Standard Training seal to be affixed to their Basic Training Certificates. The examination will be set by the Mine Rescue Station Superintendent

First Day.—Approximately 4 hours.

1. Class enrolment and organization of teams.

2. Lecture.

Explanation of Standard Training and what is expected of men taking this training.

Testing and wearing Drager apparatus.

Problems in travelling as a team.

3. Practice.

The men, properly dressed and equipped with Drager Oxygen Breathing-apparatus, should make the field tests as a team.

Fig. 2.—Standard Seal. (red)

The team should then proceed to the selected fresh air base underground. The ideal place for this work is a drift or crosscut approximately 1,500 to 2,000 feet in length, with several openings leading from it.

4. Team discipline, instruction and practice.

Instruction and practice in the following matters should be given: how to walk as a team; how and why team members are fastened together when travelling in smoky atmospheres; passing the team through a door; rates of travel and how to mark route and end of route in atmospheres of different visibilities; travelling by sense of touch with the feet; how track switches in the route travelled should be turned.

The foregoing procedure should be repeated until everyone is familiar with each routine.

5. Return to lecture room.

Recharge oxygen bottles and empty regenerators; sterilize apparatus, replace full oxygen bottles in apparatus.

6. Discussion on the day's work.

Second Day.—Approximately 4 hours.

1. Lecture.—Demand types of Breathing Apparatus, including testing and wearing. Methane and Carbon Monoxide Detectors.

Location, establishment and requirements of a fresh air base.

Organization at the time of a mine fire and the place of the rescue team in fire procedures. Discussion of an example of a fire procedure.

Duties and responsibilities of team captain.

Mine rescue team guides.

2. Practice in setting up a Fresh Air Base.

Improvising with available materials from the mine,

and using equipment from the government rescue truck, and from the rescue station.

3. Questions and discussion.

Third Day.—Approximately 4 hours.

1. Practice underground.

A place should be selected having a muck pile where men may shovel and also one where they may practice climbing ladders. These places should be inspected by a competent person before the apparatus men enter them.

(a) Practice in mucking.

Mucking shovels will be required for one section of the team. Men will alternate at the work. Each man should be equipped with a set of Drager apparatus, a Type N mask and auxiliary equipment.

Men should proceed to the working places in Drager apparatus, but not "under oxygen."

During 10-minute periods of shovelling the team should be shown the value of proper adjustment of Drager apparatus harness.

With men "under oxygen" start mucking in 5-minute periods. Emphasize the value of breathing slowly and deeply and setting up a rhythm while performing work of this nature. The captain of the team should keep his men under close observation, paying particular attention to the inflation of the breathing-bag.

Remove apparatus and allow a suitable rest period.

(b) Put on Type N masks.

Practice in climbing ladders. A raise is the best place for this work.

In this work also it is important for the team captains to watch the men's breathing rate.

2. Return to lecture room.

Recharge oxygen bottles and replace in apparatus; empty regenerators; sterilize apparatus.

3. Lecture on the oxygen Inhalator and Resuscitator.

Explain their different purposes. Let men operate them on each other.

Fourth Day.—Approximately 4 hours.

1. Practice in building barricades, underground or in a training-tunnel.

Equip the men with Drager apparatus. Supply them with tools such as hammers, saws, measuring sticks, axes and nails. Provide such materials as 2 x 4's or lagging, 1 x 8 lumber or shiplap, brattice or similar cloth. Arrangements should be made to have the materials at the working place before the team arrives.

On going underground the teams should be in apparatus but not "under oxygen" for the first part of the training. Erect a brattice-type barricade. The team captain should take complete charge.

Have the men get "under oxygen" and erect another brattice barricade making an air-lock.

Allow a suitable rest period.

Tear down the barricades.

Have the men remove the facepiece, but continue to wear the apparatus and erect a lumber barricade, using the reverse clapboard method.

When men are familiar with this method have them get "under oxygen" and erect a sandbag barricade.

2. Return to lecture room.

Recharge oxygen bottles and empty regenerators; sterilize apparatus.

3. Lecture and Demonstration of Oxygen Pump.

(Drager and/or M.S.A.)

4. Question and discussion to end of period.

Fifth Day.—Approximately 4 hours.

1. General practice, underground or in a training-tunnel.

Equip the men with Drager apparatus. Practice should be done in fairly heavy smoke.

"Under oxygen," put into practice the training that has been given the team in previous drills.

Repeat the drills in which the teams are not proficient.

Sixth Day.—Approximately 4 hours.

Written and oral examination in the lecture room.

Fig. 3.—Advanced Seal. (gold)

Advanced Training

An Advanced Training Course will be given to those men who have completed the Basic and Standard Training Courses and have been granted the Certificate and Seal in recognition.

A minimum training period of 2 years must elapse before a team member is eligible to take the Advanced Course. This enables each trainee to become familiar with all phases of mine rescue training through attendance at twelve training periods.

The Advanced Course consists of 16 hours of lectures, discussions and demonstrations. Gas sampling, analysis, underground fires, causes and control of. Slide films and movies may be used.

The examination for this course will be set and supervised by the Inspector of Mine Rescue Training or by a person authorized by the Director.

Successful candidates will be granted a gold seal to be affixed to their certificates.

Supervisory Staff Training

This course is designed for Supervisors, who should be trained so that they are able to supervise an emergency which involves the use of mine rescue teams and the use of mine rescue apparatus.

At the completion of the course an examination will be held by the Inspector of Mine Rescue Training, in collaboration with the mine mangement, and a seal to be affixed to his Basic Training Certificate will be issued to each successful candidate.

The time allowed and arrangements for the lectures and demonstrations should be arranged between the instructor and the mine management before the commencement of the course.

Fig. 4.—Supervisory Seal. (*gold*)

The course consists of three parts—

(1) Basic Training, as already outlined. Lectures and practice.

(2) Modified Standard Training. Lectures and practice in the care, use and maintenance of respiratory breathing-apparatus, and the detection of mine gases and their physiological effects.

(3) Special Supervisory Training. Such lectures and practice as may be found applicable to supervisory problems in mine rescue and recovery operations in co-operation with the mine management.

Management Course

This course is designed to assist Senior Supervision and Managers in some of the problems that would be encountered in forming policy and direction of mine rescue operations at the time of a mine fire. It is mainly a discussion course dealing with such subjects as:—Limitations of teams and equipment: Care of teams, health, meals, age limits, medical examinations: Causes, stages and control of mine fires: Sampling and analysis of mine fire atmospheres and interpreting results: Fire procedures and fire organization.

Refresher Courses

All active mine rescue teams should receive at least an 8-hour refresher course every two months. This course comprising the Standard and Advanced Training is found necessary in order to maintain the efficiency of the mine rescue and recovery organization.

All other trainees such as reserve men or specialists should receive a refresher course, particularly in the wearing of apparatus every six months.

CHAPTER III

Mine Gases, Their Occurrences, Properties, Effects on Human Beings, and Treatment of Persons Affected by Them

Air

Air is the transparent medium surrounding the earth, in which plants, animals, and human beings live and breathe. It is a mixture of several gases, which, though ordinarily invisible, can be weighed, compressed to a liquid, or frozen to a solid.

Pure, dry air at sea level contains by volume the following gases: Oxygen (O_2) 20.94 per cent.; Nitrogen (N_2) 78.09 per cent.; Carbon Dioxide (CO_2) 0.03 per cent.; and Argon 0.94 per cent. Traces of other gases such as hydrogen, helium, etc., are also present.

The air in a well-ventilated mine seldom shows any depletion of the oxygen content.

Mine air may be contaminated by the presence of other gases such as carbon monoxide, sulphur dioxide, hydrogen sulphide, methane and oxides of nitrogen. The presence of these gases may be due to any of the following: (1) after effects of blasting or other explosions; (2) after effects of mine fires; (3) exudations from ore or country rock, as with methane; (4) decay of mine timber; (5) absorption of oxygen by water or oxidation of timber or ore. Except in the case of fire, positive ventilating currents of sufficient quantity will prevent any dangerous accumulation of these gases. Gases may affect people either by their combustible, explosive, or toxic qualities or, if inert, by the displacement of oxygen. The effects may be due to varying atmospheric conditions, and may be classified as follows:—

Altitude	Breathing becomes more laborious as the altitude increases. This is not dangerous unless conditions are extreme or the labour arduous.
Temperature	High temperatures with low humidity are not dangerous except from the blistering effect of heat.
Humidity	High temperatures with high humidity are very enervating and cause considerable discomfort.
Impure Air	(*a*) Air deficient in oxygen is not dangerous unless the oxygen content is below 16 per cent., or unless the oxygen has been displaced by toxic gases. (*b*) Non-toxic gaseous impurities are not dangerous unless gases have displaced the oxygen content to below 16 per cent. (*c*) Some toxic gaseous impurities, even in very low concentrations, have deadly effects. Effects may be sudden or gradual according to the concentration of impurity. See descriptions of individual gases for further details

Oxygen (O_2)

Oxygen, a colourless, odourless, tasteless gas, is the most important constituent of air. It is necessary for the support of life and combustion. Men breathe most easily and work best when the air contains approximately 21 per cent. of oxygen, but they can live and work, though not as well, when there is less oxygen. When the oxygen content is about 17 per cent. men at work will breathe a little faster and more deeply. The effect is about the same as when going from sea level to an altitude of 5,000 feet. Men breathing air containing as little as 15 per cent. of oxygen usually become dizzy, notice a buzzing in the ears, have a rapid heartbeat, and often suffer headaches. Very few men are free from these symptoms when the oxygen in the air falls to 10 per cent.

The flame of a safety lamp or candle is extinguished when the oxygen falls to about 16.0 per cent. A carbide

lamp flame will burn in an atmosphere containing as little as 12.5 per cent. of oxygen.

Since oxygen is more soluble in water than nitrogen, air in a confined area, when exposed to water, will probably have a lowered oxygen content. As an example, the oxygen content of the air from the hydraulic compressed-air plant at Ragged Chutes on the Montreal River is lowered to about 17.7 per cent. of oxygen and a consequent rise in nitrogen content occurs.

Oxygen percentage higher than the normal 20 to 21 per cent, apparently has no injurious effect on men. This is found to be the case in the use of self-contained oxygen breathing-apparatus. There is no noticeable effect after successive periods of wear. Oxygen in high percentages, as used with the oxygen breathing-apparatus, helps men to work with less fatigue. However it is dangerous to breathe pure oxygen while the body is subjected to greater than 15 psi. above normal pressure, such as in caisson or tunnel work, for even very short periods of time. (U.S. Navy Diving Manual.) Lorrain Smith, the well-know physicist, states that irritating effects of oxygen are only found in human beings after they have been exposed for 48 hours or more in an atmosphere containing 80 per cent of oxygen, at normal atmospheric pressure.

The effects of oxygen deficiency near or below sea level are the same as those due to the reduction of oxygen at high altitudes. At approximately 7 per cent. of oxygen the face becomes leaden in colour, the mind becomes confused, and the senses dulled. When there is no oxygen in the atmosphere, loss of consciousness occurs in a few seconds without any warning symptoms. J. S. Haldane, the British physicist, says that loss of consciousness in air deprived of oxygen is quicker than in drowning; not only is the supply of oxygen cut off, but that previously in the lungs is rapidly removed and used up; loss of consciousness is quickly fol-

lowed by convulsions, then by cessation of respiration. Oxygen may be so lacking as to imperil life before one realizes the danger.

Some of the causes of oxygen deficiency underground are:— absorbtion by water or certain types of rock, ore or fill; the breathing of men in confined spaces; displacement by methane, carbon monoxide or other gases; heating conditions or combustion.

Carbon Dioxide (CO_2)

Carbon Dioxide is a product of the decomposition and/or combustion of organic compounds in the presence of oxygen, and also of the respiration of men and animals. It is a colourless, odourless gas which, when breathed in large quantities, may cause a distinctly acid taste. It will not burn nor support combustion. Carbon dioxide, being heavier than air, is often found in low places and abandoned mine workings, and is a normal constituent of mine air. The proportion of carbon dioxide in mine air is increased by the process of breathing, by the burning of flame lamps, by fires, explosions and blasting.

The following table shows the effect upon a human being of increasing amounts of CO_2 in the air breathed:—

Percentage of CO_2 in atmosphere	Increase in respiration
0.5%	— Slight
2.0%	— 50%
3.0%	— 100%
5.0%	— 300% and laborious
10.0%	— Cannot be endured for more than a few minutes.

Carbon dioxide in air has these effects when the oxygen content remains approximately normal and the individual is at rest. Moving around or working increases

the symptoms and the danger is greater than when the individual is resting. Concentrations of over 5 per cent. of carbon dioxide in the air are usually accompanied by an appreciable lowering of the oxygen content.

Carbon Monoxide (CO)

Carbon monoxide gas constitutes one of the greatest hazards to life in underground mining. It is one of the products of combustion in normal blasting operations and is dangerous unless adequate ventilation is provided. It is also produced by such abnormal occurrences as mine fires or gas explosions. It is a product of incomplete combustion and is produced wherever organic compounds are burned in an atmosphere with insufficient oxygen to carry the process of burning or oxidation to completion. It is a colourless, odourless, tasteless gas which, when breathed in even very low concentrations, will produce symptoms of poisoning. Carbon monoxide will burn, and air that contains 12.5 to 74 per cent. of carbon monoxide will explode if ignited. It is only slightly soluble in water and is not removed from the air to any extent by water sprays. It is slightly lighter than air, having a specific gravity of 0.967.

Carbon monoxide in excess of 0.005 per cent (50 p.p.m.), if breathed indefinitely, may eventually produce symptoms of poisoning; 0.02 per cent, (200 p.p.m.) will produce slight symptoms after several hours exposure. When 0.04 per cent (400 p.p.m.) are present and the exposure is for two or three hours, headache and discomfort usually occur. In concentrations of 0.20 to 0.25 percent, (2000 to 2500 p.p.m.), unconsciousness usually occurs in about 30 minutes. The effect of high concentrations may be so sudden that one has little or no warning before collapsing. (Fig. 5)

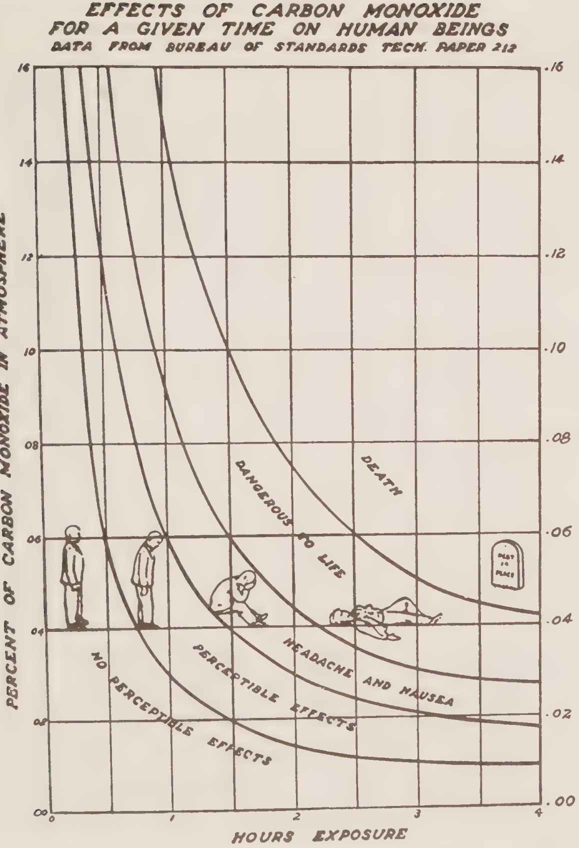


Fig. 5.—Chart showing Effects of Carbon Monoxide.

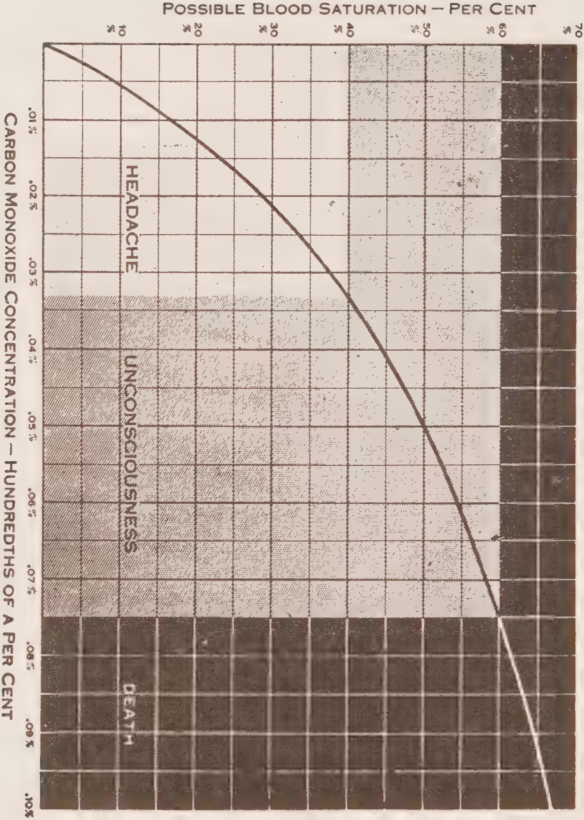


Fig. 6.—Chart showing Blood Saturations corresponding to Various Concentrations of Carbon Monoxide.

How Carbon Monoxide Acts

The oxygen absorbed from the air in the lungs is normally taken up by the blood in the form of a loose chemical combination with the red colouring matter (haemoglobin) of the corpuscles, and in this form it is carried to the tissues where it is used. Haemoglobin forms a much more stable compound with carbon monoxide than with oxygen and when saturated with the former it cannot take up oxygen.

The affinity of haemoglobin for carbon monoxide is about three hundred times its affinity for oxygen; hence, when even a small percentage of carbon monoxide is present in the air breathed, the haemoglobin will absorb the carbon monoxide in preference to the oxygen. When carbon monoxide is absorbed by haemoglobin it reduces the capacity of the haemoglobin for carrying oxygen to the tissues to a proportionate extent. It is this interference with the oxygen supply to the tissues that produces the symptoms of poisoning.

The symptoms of poisoning more or less parallel the extent of blood saturation. The first definite symptoms, during rest, make their appearance when 20 to 30 per cent. of the haemoglobin is combined with carbon monoxide. Unconsciousness takes place at about 50 percent. saturation, and death occurs at about 80 percent. (Fig. 6).

According to experiments conducted by the U.S. Bureau of Mines, the symptoms produced by various percentages of carbon monoxide in the blood are as follows:—

The symptoms decrease in number with the increase in the rate of saturation. If exposed to high concentrations, the victim may experience but few symptoms. The rate at which a man is overcome and the sequence in which the symptoms appear depend on several factors: the concentration of gas, the extent to which he is exerting himself, the state of his health and individual susceptibility, and

Percentage of Blood Saturation	Symptoms
0–10	None.
10–20	Tightness across forehead, possibly headache.
20–30	Headache, throbbing in temples.
30–40	Severe headache, weakness, dizziness, dimness of vision, nausea, vomiting, and collapse.
40–50	Same as 30–40, with more possibility of fainting and collapse, increased pulse and respiration.
50–60	Fainting, increased pulse and respiration, coma with intermittent convulsions.
60–70	Coma with intermittent convulsions, depressed heart action and respiration, possibly death.
70–80	Weak pulse and slowed respiration, respiratory failure and death.

the temperature, humidity and air movement to which he is exposed. Exercise, high temperature and humidity, with little or no air movement, tend to increase respiration and heart rate and consequently result in more rapid absorption of carbon monoxide.

Treatment for Carbon Monoxide Poisoning

The onset of carbon monoxide poisoning may be either sudden or gradual, depending on the concentration and period of exposure. Interest usually centres in the treatment of the acute or sudden form.

In the treatment of the chronic or gradual form of poisoning the most important factors are avoiding further exposure and taking a thorough rest. In the treatment of acute carbon monoxide poisoning the most important thing is to get the gas out of the blood as rapidly as possible, thus decreasing the possibility of serious after effects or even loss of life through failure of the heart and respiration. As soon as the patient begins to breathe air in which

there is no carbon monoxide the process of eliminating the gas from the blood will begin naturally. However, this normal, unaided elimination is slow and often has serious effects. It requires possibly 8 to 15 hours to reduce the carbon monoxide haemoglobin to 10 per cent. of the total haemoglobin. Inhalation of pure oxygen will remove the carbon monoxide from the blood four or five times faster. The use of oxygen alone in an inhaler is common practice because it is usually readily available owing to its general use in industry. Inhalation treatments are preferably given with an inhaler, but the oxygen may be administered by improvised apparatus or sprayed directly over the patient's face from a cylinder when an inhaler is not at hand. Caution should be observed in controlling the flow when using the gas directly from the cylinder. The cylinder should be opened and the flow regulated before the gas is directed toward the patient. No improvised mask or device should be used in which pressure can be built up and injure the patient. Because of its great efficiency an inhaler is preferable to any improvised device.

The steps in the effective treatment of carbon monoxide poisoning are as follows:—

(1) The patient should be removed to fresh air as soon as possible.

(2) If breathing has stopped, is weak and intermittent, or is present only in occasional gasps, artificial respiration should be given continuously and persistently until normal breathing is resumed, or until it is definitely established that the patient is dead.

(3) Pure oxygen should be administered, beginning as soon as possible and continuing as long as necessary—at least 20 minutes in mild cases and as long as 1 or 2 hours in severe cases.

(4) Keep the patient warm with blankets.

(5) The patient should be kept at rest, lying down to

avoid strain on the heart; later he should be given plenty of time to rest and recuperate.

It cannot be emphasized too strongly that immediate inhalation of oxygen for 20 to 30 minutes will lessen to a great extent the severity of results of carbon monoxide poisoning and decrease the possible serious after effects.

Artificial Respiration Using an Oxygen Inhaler

"Oxygen Inhaler" is a general term used to designate the apparatus. Several portable types are in general use under different trade names. (Fig. 7 & 8). They may be classed under two headings, those which act as inhalators only, with manual artificial respiration used if necessary. The second type, known as a resuscitator gives an effect of artificial respiration by mechanical control of the oxygen bottle pressure. The latter type may usually be used as an inhalator if resuscitation is not required.

Hydrogen Sulphide

Hydrogen sulphide is one of the most poisonous gases known. Fortunately only traces of it are ordinarily found on rare occasions in Ontario mines. In low concentrations its distinctive "rotten egg" odour is noticeable, but in high concentrations the sense of smell is quickly paralysed by the action of the gas and cannot be relied on for warning. The gas has a specific gravity of 1.19 and, being heavier than air, may collect at low points. A mixture of 4.3 to 46% of hydrogen sulphide in air is explosive.

Hydrogen sulphide inhaled in a sufficiently high concentration produces immediate asphyxiation; in low concentrations it produces inflammation of the eyes and respiratory tract and sometimes leads to bronchitis and pneumonia.

Sub-acute poisoning may be produced by long exposure to concentrations as low as 50 p.p.m. Immediate collapse

Fig. 7.—Type H-H Inhalator.

usually results from exposure to concentrations of 0.06 to 0.1 per cent (600 to 1000 p.p.m.) and death quickly ensues.

When explosions of dust occur in blasting operations in sulphide orebodies, the resulting gases may contain varying amounts of hydrogen sulphide, along with sulphur dioxide and possibly other sulphur gases.

Methane (CH_4)

Methane or "marsh gas" is encountered in most metal mining districts of Ontario. Flows of the gas are of variable duration according to the size of the pocket tapped. It is formed by the decomposition of organic matter in the presence of water and the absence of air or oxygen. It can be seen in the form of bubbles in stagnant pools, hence the name "Marsh Gas."

Methane is a colourless, odourless, tasteless gas. An odour caused by the presence of other gases such as hydrogen sulphide, may accompany it. Methane will burn with a pale blue non-luminous flame and still air that contains 5 to 15 per cent. of methane and 12 per cent. or more of oxygen will explode and this is its chief danger. However, the flammable and explosive range of methane is variable and all occurrences of the gas should be considered as dangerous. Where the occurrence of methane is suspected or known, adequate ventilation to dilute the gas to a harmless percentage is important.

Methane is considerably lighter than air and when found in mines is usually near the roof or in high places. Accumulations of the gas may be encountered in unused and poorly-ventilated mine workings, or when old workings are being dewatered. It may be caused by the decaying of old timbers.

Methane has no direct effect upon men, but it may displace the oxygen content of the air to such an extent

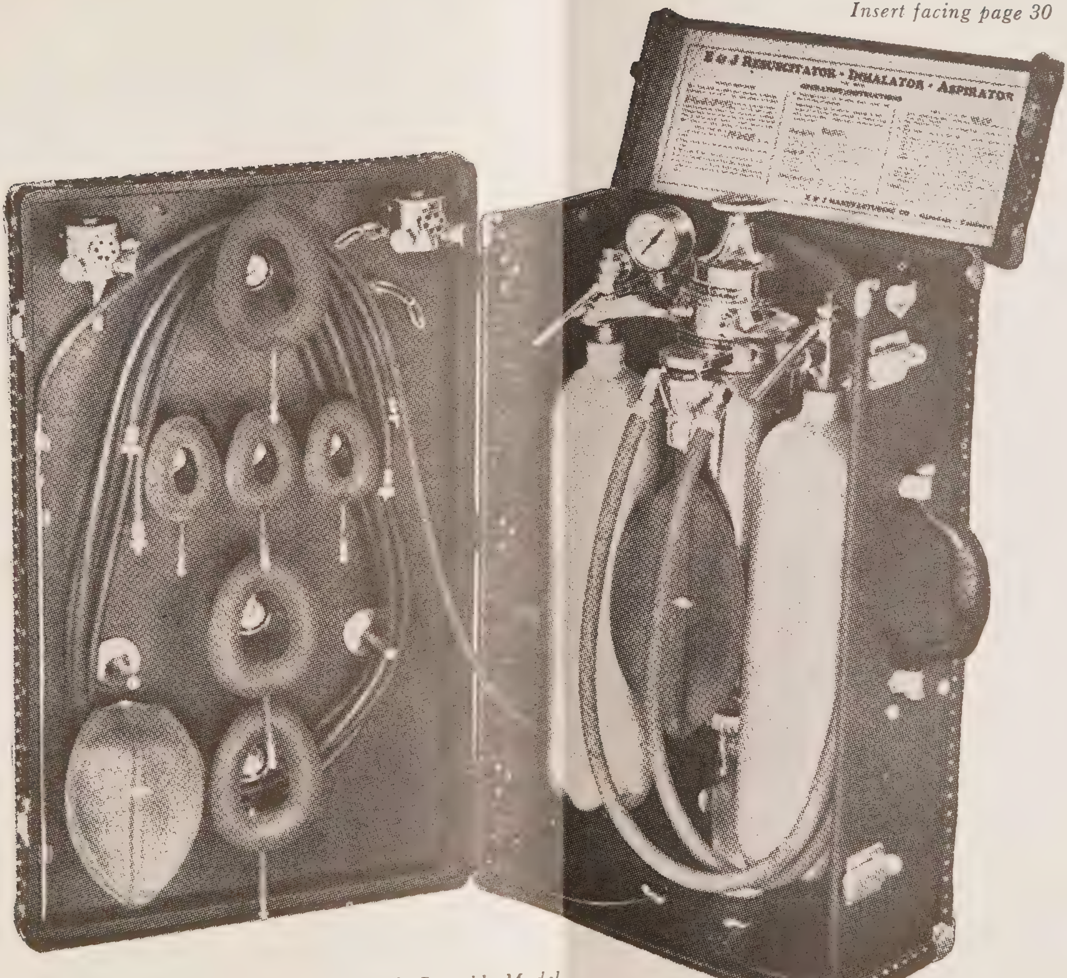


Fig. 8.—E. & J. Resuscitator, Triple Portable Model.

as to cause oxygen deficiency. An open-flame lamp or a spark may cause an explosion.

Oxides of Nitrogen

Oxides of nitrogen are formed in mines by the burning of explosives and, to a slight extent, by their detonation. They can usually be detected by the "burned-powder" odour familiar to blasters and by the reddish colour of nitrogen peroxide fumes, which are formed when the nitric oxide produced by the explosion comes in contact with the air. Hall and Howell report that gases collected from the burning of 40 per cent. gelatin dynamite contained 11.9 per cent. of oxides of nitrogen. When explosives having properly proportioned components are completely detonated they usually produce exceedingly small percentages of oxides of nitrogen, which are considered harmless. Explosives from which the wrapper has been removed may produce harmful percentages of oxides of nitrogen, even when detonated.

Oxides of nitrogen corrode the respiratory passages, and the breathing of relatively small quantities may cause death. The effect is unlike that of carbon monoxide in that a person may apparently recover and then suddenly die several days later. Nitrogen peroxide is probably the most irritating of the oxides of nitrogen. Its effects on the respiratory passages usually are not manifest until several hours after exposure, when oedema and swelling take place. This irritation may be followed by bronchitis or pneumonia, frequently with fatal results. One Hundred parts per million of nitrogen peroxide may cause dangerous illness if breathed for a short time, and 700 p.p.m. is fatal if breathed for about 30 minutes or less.

Oxides of nitrogen are also a component of diesel engine exhausts.

Sulphur Dioxide (SO_2)

Sulphur dioxide is a colourless, suffocating, irritating gas with the familiar pungent, sulphurous odour. It is sometimes given off by the detonation of explosives and is present at the time of mine fires in sulphide orebodies.

Sulphur dioxide is very poisonous, but, owing to its irritating effect on the eyes and respiratory passages, is intolerable to breathe for any length of time in dangerous concentrations.

Nitrogen (N_2)

Nitrogen is a colourless, odourless, inert gas. It is not combustible, nor will it support combustion. It has no physiological effect on man and is only dangerous if it occurs in such concentrations that it dilutes the air sufficiently to cause the oxygen content to fall below a safe limit. This dilution may result from the oxidation of various substances or from the consumption of oxygen in supporting the combustion of an active fire, thus robbing the mine atmosphere of a part of its oxygen. The oxygen may be reduced to a very low point and the residual nitrogen mixed with the products of combustion such as carbon dioxide, carbon monoxide, sulphur dioxide, etc.

Hydrogen (H_2)

Hydrogen is a colourless, odourless, tasteless gas. It is not dangerous to breathe, but is combustible and is dangerous because of its explosibility (4.1 to 74% in air). In addition to this, at the time of a mine fire it may unite with carbon to form explosive concentrations of hydrocarbons.

The gas is found in normal air in very small quantities. It is sometimes found in the mine atmosphere during or after a fire, particularly when the rocks have been heated to incandescence. It is also a product of the electrolytic action in the wet batteries used in mine locomotives.

Smoke

Smoke consists of exceedingly fine particles of solid and liquid matter suspended in the atmosphere. These particles are composed mostly of soot or carbon, together with tarry substances, mainly hydrocarbons. Asphyxiating and irritating gases and vapours are usually mixed with the smoke. Hydrocarbons in sufficient concentration may be explosive.

The Damps

The word "damp" is seldom associated with any of the gases or mixtures of gases found in metal mines. Such gases or mixtures do occur, however, in metal mines. The term "damp" is commonly used in descriptions of gases involved in coal mine explosions.

Firedamp

"Firedamp" is a term often given to methane, but which applies more properly to a mixture of methane and air. The mixture usually becomes explosive when it contains approximately 5 to 15 per cent. of methane and the oxygen content is 12 per cent. or more.

Afterdamp

"Afterdamp" is a product of a mine fire or explosion. As a rule it consists mainly of carbon dioxide and carbon monoxide, and has a low oxygen and high nitrogen content.

Blackdamp

J. S. Haldane defines "blackdamp" as an accumulation of carbon dioxide and nitrogen in proportions larger than those found in normal air. It is found in abandoned workings or sealed areas, and in wells. Blackdamp may also be formed by mine fires or explosions of firedamp in mines, and in such instances may contain fairly large quantities of carbon monoxide.

Hazards Due to Gases During or After Mine Fires or Explosions

During and following metal mine fires the two greatest hazards to life are poisoning from the breathing of carbon monoxide and suffocation in an atmosphere deficient in oxygen. Conditions which cause contamination in mine atmospheres are:

Carbon Monoxide.—This gas is always present at the time of an underground fire and gives little or no warning.

Oxygen Deficiency.—This condition occurs because of the consumption of oxygen by combustion or chemical reaction and its replacement by toxic or inert gases. Precautions must always be taken against it.

Smoke.—The hazard is due to its irritating qualities and obstruction of vision. It may be explosive.

Danger of Explosion.—Hydrocarbon gases caused or generated by fire (as in Smoke) may explode.

Methane.—This gas is not produced by mine fires or explosions but may cause them. Its presence in a mine during rescue or recovery operations creates a considerable hazard.

Sulphur Dioxide.—This gas is present at the time of a fire in a sulphide orebody. Because of its irritating qualities it gives advance warning when in less than toxic concentrations.

Other gases.—Hydrogen sulphide, nitrous oxides, etc., are not very likely to be encountered, but the possibility of their occurrence should be kept in mind. Hydrogen sulphide sometimes indicates the presence of methane.

Important Characteristics of Mine Gases

The important characteristics of mine gases are set out in the two following tables.

Gas	Sol. in* H_2O	Ex-plosive	Explosive Range per cent.	Com-bustible	Colour	Odour	Taste	Dangerous to breathe
Air	.019	No	....	No	None	None	None	No
Oxygen	.031	No	....	No	None	None	None	No
Carbon dioxide	.878	No	....	No	None	None	None	Yes[1]
Methane	.033	Yes	5.0 to 15	Yes	None	None	None	No[2]
Carbon monoxide	.023	Yes	12.5 to 74	Yes	None	None	None	Yes[3]
Hydrogen sulphide	2.672	Yes	4.3 to 46	Yes	None	Yes	Yes	Yes[3]
Nitrogen peroxide	....	No	....	No	Red	None	Yes	Yes[3]
Sulphur dioxide	....	No	....	No	None	Yes	Yes	Yes[3]
Hydrogen	.018	Yes	4.1 to 74	Yes	None	None	None	No
Nitrogen	.016	No	....	No	None	None	None	No
Gasoline (for comparison)	.21	Yes	1 to 6%	Yes	None	Yes	Yes	Yes[3]

[1] In fairly high concentrations, above 5% or more.
[2] Sometimes accompanied by H_2S.
[3] Extremely dangerous even in very low concentrations.
*C.C. of gas absorbed per c.c. of water at 20°C or 68°F at atmos pressure.

Gas	Formula	Molecular Weight	Weight at 0° C. and 760 mm. Hg. Grams per litre	Pounds per cubic foot	Specific Gravity, air = 1
Air	....	......	1.2928	0.08067	1.0000
Oxygen	O_2	32.00	1.4291	0.08918	1.1054
Carbon dioxide	CO_2	44.00	1.9768	0.12335	1.5291
Methane	CH_4	16.03	0.7168	0.04473	0.5545
Carbon monoxide	CO	28.00	1.2504	0.07805	0.9672
Hydrogen sulphide	H_2S	34.09	1.5392	0.09605	1.1906
Nitrogen peroxide	NO_2	46.01	2.0548	0.12822	1.5894
Sulphur dioxide	SO_2	64.07	2.9266	0.18262	2.2638
Hydrogen	H_2	2.01	0.0899	0.00561	0.0695
Nitrogen	N_2	28.02	1.2507	0.07804	0.9674

Questions on Chapter III

1. What are the main components of air and in what percentages do they occur?

2. Give the characteristics of oxygen.

3. Will oxygen burn or explode if it is pure?

4. (a) What gases are we most likely to encounter in a fire in a mine?

(b) Name the most deadly of these gases. Describe it.

(c) At about what percentage in air does this gas become dangerous to breathe?

(d) What first aid treatment is recommended for persons affected by this gas?

5. What other gases may be found in a mine fire in sulphide orebodies?

6. What gas or gases are usually associated with blasting?

7. What gases are usually present with smoke?

8. What explosive gases, if any, are we likely to find in mine air?

9. Name some of the causes of deficiency of oxygen in air.

10. What colour is the face when the oxygen content of the air is low?

11. What difference is there in the symptoms of oxygen deficiency between air at sea level that has a low oxygen content and the atmosphere at 5,000 feet?

12. When a person succumbs to oxygen deficiency does respiration or the heartbeat stop first?

13. Without the use of special instruments is there any way we can detect the presence of certain gases?

14. (a) With what gas do we associate the smell of rotten eggs?

(b) In a very small concentration of this gas what are the first noticeable symptoms?

15. Does breathing pure oxygen at atmospheric pressures have any adverse effect on men?

16. What are considered the two greatest hazards to men during mine fires with regard to mine air?

17. What are the symptoms of carbon monoxide poisoning?

CHAPTER IV

Methods of Detection of Mine Gases

Various methods and devices are in use for detecting certain toxic, noxious and explosive gases in mine air. The presence of carbon monoxide and methane and deficiency of oxygen are the greatest hazards encountered during mine rescue or recovery operations and there are accurate and speedy means of detecting them. Hydrogen sulphide and sulphur dioxide may be detected by the sense of smell before they are present in dangerous quantities. Other gases, such as oxides of nitrogen and certain hydrocarbons usually, but not always, occur in quantities too small to be a hazard and their proportions are determined by gas analysis. Gas analysis requires considerable time, the necessary apparatus, and a knowledge of chemistry.

Carbon Monoxide

Several rapid and sufficiently accurate methods of detection of carbon monoxide are in common use. Two of these are:

1. The Colorimetric Carbon Monoxide Tester.
2. The Drager Gas Detector.

COLORIMETRIC CARBON MONOXIDE TESTER

This instrument (Fig. 9a) consists of an aspirator bulb with an adjustable control valve, a replaceable indicating tube and a standard colour scale. The operator must have good eyesight to make a comparison between the colour scale and the indicating tube.

Inspecting the Detector Before Use

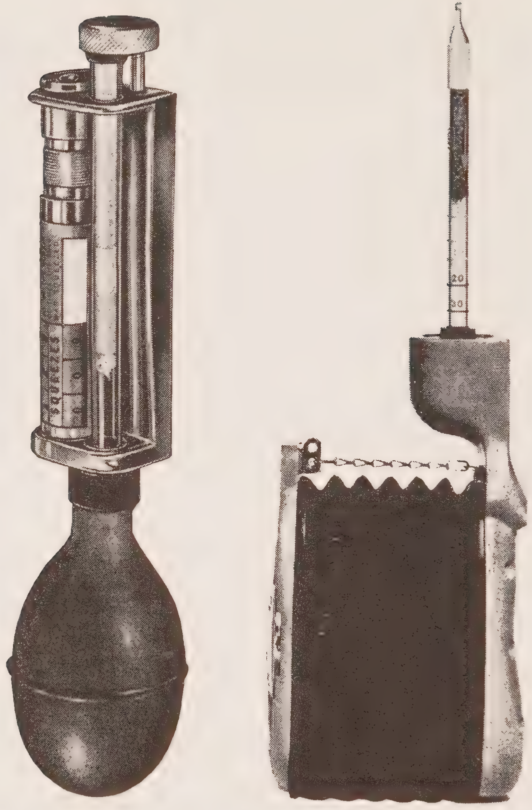
To test the instrument for air tightness, deflate the bulb fully, place a finger firmly over the inlet opening and observe the bulb. If the bulb tends to inflate, the rubber band over the outlet opening, or the bulb itself may be leaking.

Thirty seconds (+or−3) are required to inflate the aspirator bulb when all air is exhausted from it with no tube in place. Adjust flow control valve screw, if necessary, using a small screwdriver to obtain this rate. If proper flow cannot be made by adjustment, remove valve screw and clean orifice with a fine wire. Replace screw and adjust to obtain correct flow.

Use of Tester

In use, the sealed ends of the indicating tube are broken and the tube is inserted in the tube holder of the tester with the empty end of the tube towards the aspirator bulb. A sample of air, controlled by a specially designed metering orifice, is then aspirated through the tube. When the air sample contains carbon monoxide, the yellow silica gel in the detector tube turns green, the shade and intensity being directly proportional to the concentration of carbon monoxide in the air sample. The varying shades of green shown on the colour scale are easily distinguished and the comparable carbon monoxide concentrations which they indicate are clearly marked in percentages.

The tester is capable of indicating the presence of carbon monoxide in air from 0.001 to 0.10 per cent. (10 to 1000 p.p.m.) A special chemical is placed on either side of the silica gel to act as a guard. The guard chemical removes water vapour, gasoline vapour, and other interfering substances ordinarily encountered with carbon monoxide. One squeeze of the suction bulb is recommended to obtain an accurate indication of carbon monoxide concentration in the range of 0.005 to 0.10 per cent. In the range from .001 to .005 more accurate colour determinations may be



(a) (b)

Fig. 9—(a) Colorimetric Carbon Monoxide Tester.
(b) Drager Gas Detector

obtained by giving the bulb from two to five squeezes. The tube will retain any color change indicating carbon monoxide for a period of at least 8 hours providing the broken ends are sealed immediately after testing. New tubes may be kept indefinitely, providing the ends are not broken. The tube may be used only once if any colour appears, but several tests may be made if no colour change takes place.

Testing Diesel Exhaust with the Colorimetric

Where diesel motors are used in mining operations, it is necessary that frequent tests be made to check the amount of carbon monoxide in the exhaust gases. A scrubber, filled with gasorbent is available, and should be attached to the inlet of the instrument. The gasorbent prevents the passage of all gases, except carbon monoxide, which would have an effect on the silica gel. Readings may then be taken in the regular manner. Samples should not be taken directly from the exhaust manifold, as hot gases will cause errors in the result.

DRAGER GAS DETECTOR

This instrument, (Fig. 9b) consists of a spring-loaded rubber bellows with a capacity of 100 cubic centimeters of air, and a replaceable indicating tube. Air to be tested is drawn directly into the indicating tube before passing into the bellows, and thus the instrument requires no purging before inserting the tube. The outlet valve of the bellows provides so little resistance that the air will not return through the testing tube.

The Drager Gas Detector is designed for the testing of a number of gases, using various indicating tubes. We are concerned here primarily with the testing of carbon monoxide.

Two different types of indicating tubes are available for testing of low and high quantities of carbon monoxide. The

low-range tubes are used in testing CO from 10 to 3000 parts per million, (0.001% to 0.3%). The high-range tube, is used for testing CO from 0.3% to 4%. All tubes contain filtering chemicals to remove hydrocarbons and other gases that could affect the reading of the instrument.

Inspecting the Detector before use

The bellows should be squeezed once or twice to be sure the outlet valve is operating. Insert an unbroken indicating tube into the inlet and collapse the bellows. The bellows should remain collapsed unless the outlet valve is leaking. It is not necessary to check the time taken for the bellows to inflate, as that action is controlled by the resistance built into each indicating tube. If the outlet valve is leaking, the valve cover plate may be removed and the valve seat inspected or cleaned.

Use of the Detector

To use the detector, select the proper CO indicating tube, depending on the concentration of CO that may be expected due to conditions that are known. Break the sealed ends of the indicating tube by inserting them in the "breaker" attached to one end of the drag chain on the bellows. Insert the tube firmly into the detector inlet so the passage of air will be according to the arrow on the tube, squeeze the bellows fully to expell the residual air, and then allow the bellows to re-fill completely. If the air sampled contains carbon monoxide, a dark stain will be noticed extending downwards through the white crystals. The percentage is measured according to the distance the stain extends into the crystals.

The figures 1, 5, 10, 20 and 30, painted on each of the low-range tubes are interpreted when a 1-squeeze test has been made, as 100, 500, 1000, 2000 and 3000 parts per million, (.01; .05; .1; .2 and .3%) respectively. If the colour change is too slight to be readily observed after 1

squeeze, or does not extend as far as the first marking, nine more squeezes should be given. The above figures would then indicate 10, 50, 100, 200 and 300 parts per million. (.001; .005; .01; .02 and .03%)

The high range tube has the figures 0.5; 1.0; 2.0; 3.0; and 4.0 painted on it, and a 1-squeeze test is interpreted directly "in percentage". A 10-squeeze test is interpreted as .03; .05; .1; .2; .3 or .4% respectively.

In either tube, the reading is taken at the lowest level of the general discoloration, and NOT at the deepest point of color penetration.

All tubes have a band on the upper end on which can be written data concerning the test. Tubes, once colored will not change color for several hours, and so may be read later under better lighting conditions than found in testing areas underground. Tubes that have been used, and no color reaction obtained, may be re-used up to 10 times or until color is found, in one day. Once colored, they must not be re-used.

When testing diesel exhaust or other high mixtures of hydrocarbons for carbon monoxide, a carbon pre-tube, filled with activated charcoal should be used as an additional filter to prevent the hydrocarbons from reaching the testing crystals. Exhaust gas should not be sampled directly from the manifold, but should be passed through some form of cooler to bring the temperature into the range of 50° to 112° Fahrenheit.

Methane

Methane Detectors

The flame safety lamp has been the standard means used for detection of methane in the past and can be used for the detection and determination of methane gas in air within a range of 1.0 to 4.0 per cent. However, a thoroughly trained and experienced operator is required

to obtain an accurate determination of methane by this method. Electrical thermo-coupled detectors are now replacing the flame safety lamp in Ontario mines. The method of testing for methane with the flame safety lamp is described later in the text.

M.S.A. METHANE "SPOTTER"

The M.S.A. Methane Spotter is a compact electrically-operated instrument designed for the detecting and measuring of methane gas in air, with a range of 0-5% (0-50,000 p.p.m.).

This detector employs a balanced electrical circuit and is powered by two re-chargeable 2.4 volt nickel cadmium batteries. The diffusion head, or sensor, enclosing the detecting elements, is located on top of the instrument. These elements consist of two pelletized filaments, or pelements, one of which is catalytically treated and the other is not.

A meter dial indicates methane readings from zero to 5 percent, with graduations of 0.25 percent. A battery charging receptacle is provided on the upper right side of the case. Fully charged batteries should provide approximately 200 readings.

Principle of Operation

When a mixture of methane gas in air comes in contact with the pelements, the gas burns, thus raising the temperature of the pelements, increasing their electrical resistance. This change in resistance unbalances the electrical circuit, and the amount of unbalance is indicated on the meter, calibrated in terms of percentage of methane.

Operation of the Instrument

1. Check the mechanical zero. Hold the instrument in an upright position and observe the pointer on the meter scale. It should rest on zero or within the black area at zero.
2. Check battery voltage.

Fig. 10(a)

M.S.A. Methane "Spotter"

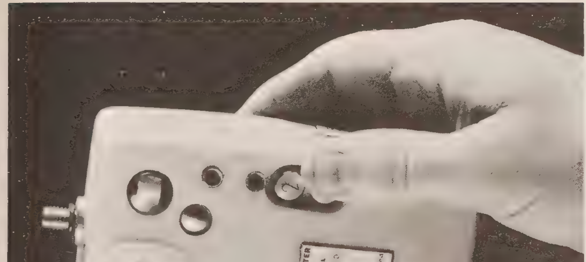


Fig. 10(b)

G-70 Methanometer

(a) This is done by depressing both buttons located on the face of the instrument at the same time. Hold the buttons depressed for at least 15 seconds.

(b) The pointer should swing upscale then gradually return downscale and stop.

(c) If the pointer stops within the BATTERY segment of the meter scale, the battery is adequately charged for testing.

(d) If the pointer drops below the BATTERY segment of the meter scale, the battery must be recharged.

3. *Check the electrical* zero (to be done in gas-free atmosphere).

(a) Servicing and adjustments should be done by a qualified person.

(b) Depress the TEST button and hold for 15 seconds.

(c) At the end of this time, the meter should indicate within the black area at zero.

(d) If the instrument does not read zero, an electrical zero adjustment must be made.

Battery Charging

1. The batteries should be charged when the battery test gives an indication to the left of the BATTERY segment of the dial.

2. Using the charger.

(a) Raise the receptacle cover on the right side of the spotter and insert the plug of the charger.

(b) Insert the A. C. plug into a receptacle providing a source of 110-120 volts A. C.

(c) Charge the battery pack for 16 hours.

3. Overcharging will result in reduced battery efficiency. Proper use of the charger should enable the battery pack be recharged 300 to 500 times before requiring replacement.

Testing for the Methane

1. Depress the TEST button and hold it for 15 seconds or until the pointer comes to rest.

2. Read the meter indication.

This instrument should not be used for measuring methane content beyond 5 percent.

THE G-70 METHANOMETER (Fig. 10b)

The G-70 methanometer is a hand held, electrically operated instrument, used to detect and accurately measure the amount of methane gas present in the atmosphere of the mine in a range of 0 to 5 percent. An excess of 5 percent will be indicated but without accuracy.

The instrument operates according to the principles of the Wheatstone bridge circuit in which an air sample is drawn through the instrument and the combustible content of the air is burned on a wire element. This element is one leg of the Wheatstone bridge circuit. As the temperature of the detector element increases, the electrical resistance will also increase and the Wheatstone bridge circuit becomes unbalanced.

The degree of change in the electrical circuit is indicated by a meter. The meter gives a reading which is equivalent to the concentration of methane gas in the air that is being tested.

The G-70 methanometer is powered by one re-chargeable cell, the capacity of which is adequate for approximately 300 measurements of 10 to 12 seconds in duration. The voltage indicator of this cell is situated in the upper right hand corner on the front of the instrument, and will show the state of charge during each operation.

When the cell is fully discharged the pointer remains on the red area of the indicator when a test is being made. For proper testing, the pointer must remain in the white area during the test, indicating a fully charged cell.

A portable battery charger is provided for the G-70 methanometer and charging time is approximately 10 hours.

The instrument may also be fitted with telescopic samp-

ling probes of different lengths to facilitate probe sampling in difficult locations.

Preparing the Tester for Use

First check the zero setting by visual observation of the needle when the instrument is not energized.

Next the cell charge and the electrical zero are checked simultaneously:—

(a) Depress and continue to hold either range button "2" or "5". You will hear a buzzing sound which indicates that the pump is activated and a sample of air is being drawn into the instrument. When the pump action stops, the needle will deflect to the left and then return to the right which indicates that the instrument is in proper working order. If the needle comes to rest at any point other than zero an adjustment must be made.

(b) While continuing to hold the range button depressed, observe the red and white coloured voltage indicator. If the pointer remains in the red area it indicates low voltage and the instrument cannot be used to detect methane until it has been re-charged. If the pointer remains in the middle of the white area it indicates optimum working voltage and is suitable for use.

To Test for Methane

The dial shows two measuring scales, the upper scale is graduated for measuring from 0 to 2 percent methane and the bottom scale ranges from 1.8 to 5 percent.

To make the test, depress the desired range button "2" (for upper scale reading) or "5" (for bottom scale reading). The operation of the suction pump will be heard, which is automatically controlled. Hold the selected range button in the depressed position during the entire operation. The needle will deflect first to the left and then return to the right, coming to rest on the dial and indicating the methane concentration.

Ranges exceeding 0 to 5 percent can be indicated on the G-70 methanometer and would be indicated by what appears to be an abnormal or erractic behaviour of the needle.

When ranges are in the 5-15 percent range, with range button "5" depressed, the needle will deflect quickly from the zero point to the right, passing off the scale until it comes to rest at the dial stop. The pointer will rest at the stop for 2 to 12 seconds, depending upon the concentration of methane, and then return to a point left of the zero point.

The higher the concentration of methane the shorter the time for the return of the needle to the left of the zero point.

When the measurement is in the 15 to 60 percent range, with range button "5" depressed the needle will deflect only partly to the right and will return immediately to the left of the zero point, where it will remain until the range button has been released.

When the measurement is in the 60 to 100 percent range, with range button "5" depressed, and upon expiration of the pump operation time, the needle will deflect very quickly from the zero point to the left of zero where it will remain until the range button has been released.

FLAME SAFETY LAMP

Prior to the advent of electrical methane detectors the percentage of methane in an atmosphere was determined by testing with a flame safety lamp.

The testing cabinet (Fig. 12) is used to demonstrate the reaction that takes place within a Flame Safety Lamp as it is introduced into an area (a) deficient in oxygen; (b) containing various percentages of methane. It is also used to demonstrate the result of carrying a lamp with defective screens into explosive mixtures of methane.

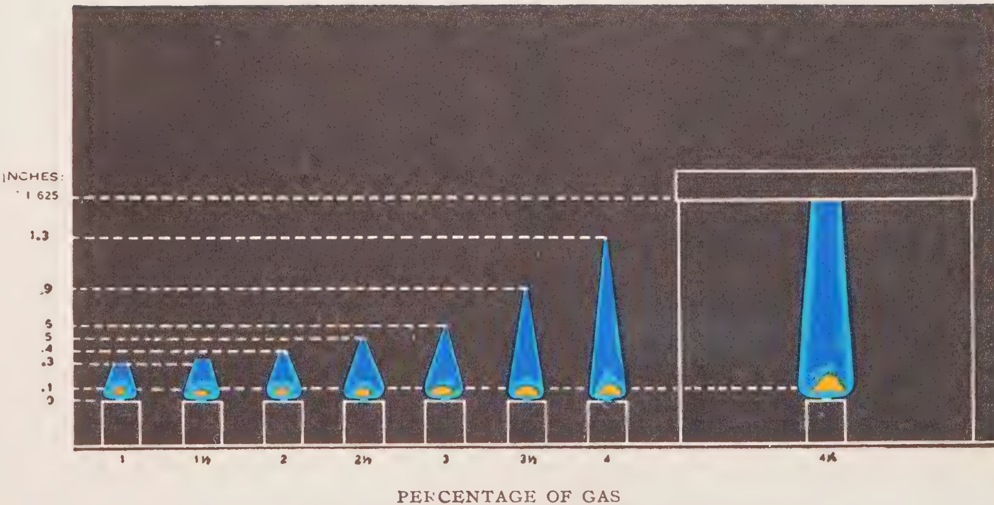


Fig. 11—Height of Gas Caps with Wolf Round-wick Lamp

* Upper limit of visible gas cap. Total height of cap indeterminate.

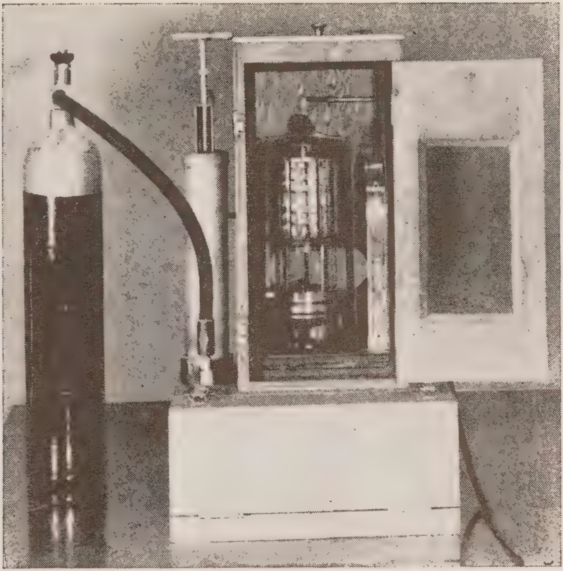


Fig. 12—Flame Safety Lamp Testing Cabinet

Uses of the Lamp

The flame safety lamp (Fig. 13) provides a ready method for determining oxygen deficiency and a means of testing for methane. It must not be used in any place known to contain acetylene, hydrogen, or a known explosive mixture of methane and air.

Electrical methane testers have largely displaced the safety lamp in testing for methane. They are comparatively accurate, safer to operate and require less experience.

The main use of the safety lamp now is in testing for oxygen deficiency. The flame of the lamp will go out if

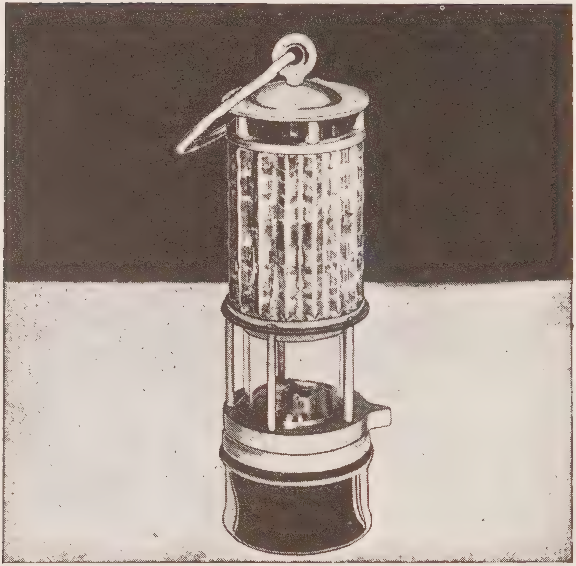


Fig. 13—Wolf Flame Safety Lamp Round-wick Type, with Key Lock.

there is less than 16 per cent. of oxygen by volume in the atmosphere. The Wolf lamp is the one generally used in Ontario. It was invented in 1883 by C. Wolf of Germany. It uses for fuel a volatile oil, such as naphtha. It has bottom feed, and a feed-screw for raising or lowering the wick.

The Parts of the Lamp

The main parts of the lamp are shown in Fig. 14. There is a steel or aluminum hood[1]. A brass or aluminum

bonnet[2] protects inner and outer wire-screen chimneys[3] which rest on top of a pyrex glass chimney[4] sitting in a brass air admission ring[5] on the top of a brass or aluminum fuel reservoir. Passing through the top of the reservoir is a tube holding the round wick, and passing completely through the reservoir is the wick adjuster and flint-type igniter. To prevent the fuel from spilling over, the fuel reservoir is packed with cotton batting. The glass chimney rests on a flexible ring[6] to allow for expansion. The brass lamp weighs about 3 pounds 6 ounces and the aluminum lamp a pound less.

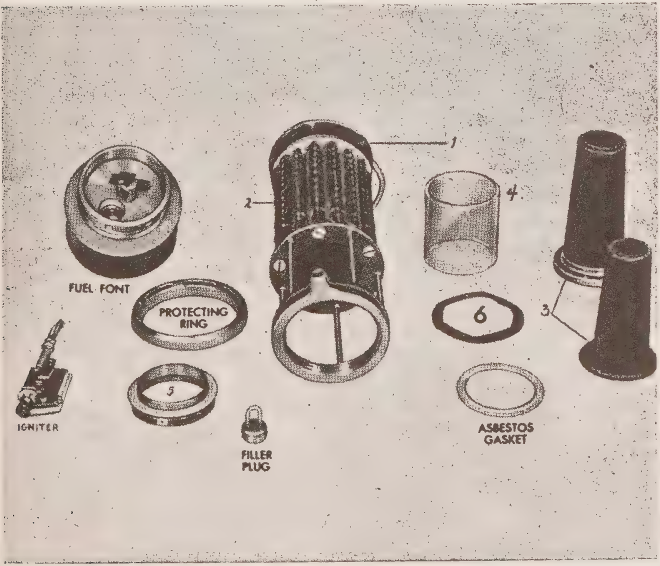


Fig. 14—Parts of Wolf Flame Safety Lamp

Care and Operation of the Lamp

Filling the Lamp With Fuel.—Only naphtha should be used for fuel in the lamp. Neither benzine nor gasoline should be used.

In filling the lamp only a sufficient amount of fuel to saturate the cotton with which the reservoir is packed should be used. After the lamp has been filled it should be turned upside down so that any excess fuel will drain out. Care should be taken to remove any fuel which may remain on the outside of the lamp after filling. This precaution is necessary, because when the lamp becomes heated this excess fuel may evaporate and enter the testing-flame, thereby tending to cause false interpretations.

Examining and Cleaning the Wire Screens.—The wire screens constitute the safety feature of the lamp. This depends on the cooling effect that a wire screen exerts on flame. Combustible gases ignite at certain fixed temperatures and if the temperature is decreased from any cause the flame is extinguished. Any deterioration of the screens, slight though it may be, is a direct source of danger. It is, therefore, very important that they should be examined carefully for indications of wear or other imperfections. Even though no indication of wear is visible, the screen should not be used for too great a length of time, since the heat of the flame oxidizes the wires, gradually reducing their diameter and decreasing their heat-conducting capacity.

The air-admission ring of the lamp is also provided with two wire screens, which require careful attention. Although they are not exposed to the heat of the flame, they should frequently be carefully examined to determine whether they are in good condition and are properly connected to the ring. If they are found to have deteriorated in any way the complete ring should be replaced. For cleaning the screen a wire-bristle brush should be

used. This brush will thoroughly clean the inside and outside of the screens.

Preparing the Lamp for Testing.—Before the lamp is used to make a test it should be carefully examined to insure that all parts are in good condition, that they fit properly, and that no parts are missing. It is very important that the screens be free from dust, oil, soot, or any other obstruction which will interfere with the air circulation through the lamp. Attention should also be given to the wick. It should be trimmed of excess crust to prevent clogging so that the fuel will feed freely and produce a flame which is stable and uniform.

Assembling the Lamp.—Care should be taken to insure that the lamp has been properly assembled after filling or cleaning. The following are some of the errors likely to occur in assembling the lamp:—(a) omitting one of the screens; (b) failing to screw the fuel font into place so as to make a tight fit between the glass chimney and the gaskets; (c) placing a defective screen in the lamp; (d) leaving out one or both chimney gaskets; (e) inserting a chipped or cracked glass chimney; (f) replacing filler plug with a missing or defective gasket.

Testing With the Lamp

In making the tests with the lamp, the following instructions should be observed:—

1. Light the lamp about 5 minutes before using for a test, so that the flame will reach its normal operating temperature. Adjust the flame so that it will be about half an inch high when burning in a normal atmosphere.

2. If the flame decreases in height and flickers, it indicates that there is a deficiency of oxygen in the atmosphere. Under this condition the flame will be extinguished completely when the oxygen content of the atmosphere is reduced to 16 per cent. When a deficiency of

oxygen is indicated in any area it should be thoroughly ventilated and retested before anyone enters it.

As a matter of interest, the following table indicates the decrease of illumination produced by a flame lamp as the percentage of oxygen in the air is decreased. When the percentage of illumination drops below 20%, a slight jar will extinguish the lamp, after which it is almost impossible to re-light.

% of O_2	% of Illumination
20.93	100%
20.30	75%
19.30	40%
18.30	12%
16.25	nil

The Testing Flame.—If a safety lamp burning in pure air with a full or slightly lowered flame is introduced into air containing 2½ or 3 per cent. of methane, no gas-cap can be seen, but the lamp-flame will get a little longer, or, as it is called, "draw" or "spire." In order to test for methane and estimate the percentage, the wick must first be drawn down carefully until the flame is very small (about 1/10 of an inch high) and shows no more than a speck of yellow light.

A low testing-flame is essential (Fig. 11), because unless the flame is lowered the light from it renders the caps invisible. The observer should make himself thoroughly familiar with the appearance of such a testing-flame when the lamp is burning in fresh air, in a main intake airway for example.

The Fuel-cap.—The observer will see a continuous pale blue line defining the top of the testing-flame, with a speck of yellow light in the middle. Above the blue line he will see a very faint fuzzy outline of paler blue; this is called the

fuel-cap. With lamps burning a volatile spirit, such as naphtha, the fuel-cap may be 1/10 of an inch in height above the top of the testing-flame.

The Gas- or Methane-cap.—When methane is present in the air another cap, called a gas-cap or methane-cap, somewhat similar in colour and appearance to the fuel-cap, is seen stretching up from the testing-flame.

It is not difficult, with practice, to distinguish a gas-cap from a fuel-cap. Unless they are distinguished, however, mistakes will occur in estimating small percentages of methane.

The illustration on p. 50 (Fig. 11) is a reproduction of photographs of the testing-flame in a safety lamp which is burning naphtha and has a round wick and the air inlets in the middle ring, and of the gas-caps as they appear above the testing-flame when the air contains different percentages of methane. The reproduction gives a fair idea of the size and shape of the gas-caps, but not of their texture and colour, which are something like those of a faint wisp of tobacco smoke. A gas-cap might be described as "the ghost of a pale blue flame."

Gas-caps and Percentages.—The gas-cap is first seen when about 1 per cent. of methane is present. It takes the form of a very faint extension or fringe at the extreme edges of the testing-flame, but it has proved impossible to photograph this.

As the percentage of methane increases, the gas-cap spreads across the testing-flame and becomes larger and clearer, until it forms a complete triangle above the testing-flame indicating that 2½ per cent. of methane is present. The triangle gets taller as higher percentages are met with until, at 4 per cent. of methane, the gas-cap begins to reach to the top of the glass, and as the percentage of methane increases still further, the cap may eventually spire up into the screen chimney.

Precautions

If the gas-cap approaches the top of the glass, the lamp should be steadily drawn back into purer air; otherwise a further slight increase in the proportion of methane may cause the mixture within the lamp to explode and put out the testing-flame. The cap should not be allowed to spire up into the screen.

Methane should not be allowed to continue to burn inside the screen of a lamp. If methane begins to burn in the screen, the lamp should be carried out to pure air and it should not be jerked or rapidly moved. If it is impossible to remove the lamp from the gas area, it should be extinguished, not by jerking it down or blowing on it, but by pulling the wick down still farther and covering the air-inlet holes so as to smother the flame.

Hydrogen Sulphide

HYDROGEN SULPHIDE DETECTORS

As hydrogen sulphide has been found only in some non-metallic Southern Ontario mines, reference in this book is simply made to the two instruments commonly available for its detection:

1. The M.S.A. Hydrogen Sulphide Detector.
2. The Drager Gas Detector (Fig. 9b) using H_2S tubes.

Oxygen Deficiency in the Atmosphere

In addition to the hazards due to the toxic effects of certain gases, the atmosphere of a mine may be dangerous because of depletion of the oxygen content and its replacement by gases such as nitrogen or carbon dioxide. This condition may be detected by the flame safety lamp.

Other Mine Gases

With few exceptions, mine gases other than carbon monoxide, methane and hydrogen sulphide can rarely be detected accurately except by chemical analysis. Some dangerous mine gases can often be detected by odour, taste, or colour, or by irritation of the eyes and respiratory passages. Sulphur dioxide gas is an outstanding example of this. Such gases, with the exception of sulphur dioxide, are rarely found in mine atmospheres in sufficient quantities to be dangerous.

Questions on Chapter IV

1. Describe the method or methods for detecting the following:—
   (a) Carbon Monoxide
   (b) Methane
   (c) Deficiency of Oxygen

2. How do you prepare the flame lamp before making a test?

3. Describe "Fuel Cap" and "Gas Cap" as seen on the flame lamp under certain conditions.

4. (a) Describe the appearance of the Drager Gas Detector.
   (b) What is the testing range of each tube?

5. What precautions must be taken when testing diesel exhaust gases with either carbon monoxide detectors?

CHAPTER V

Methods of Protection Against Mine Gases

General Considerations

The general requirements and approvals of breathing-devices as laid down by the U.S. Bureau of Mines have been generally accepted by the Ontario Division of Mines.

The Value of Slow, Deep Breathing When Wearing Apparatus

To use gas masks or other breathing-devices properly the art of deep breathing should be practiced until it becomes habitual. The value of slow, deep breathing at all times can be demonstrated whether wearing breathing-devices or not. This is best shown by doing some exercise that causes panting or quick breathing. Draw in several deep, controlled breaths, slowly and evenly, inhaling as much air as possible. It will be noticed that the normal rate of breathing can be resumed quickly and easily without panting.

Resistance through the apparatus must be expected when breathing-devices are worn. This resistance can vary from a few ounces to as much as 3 or 4 psi.*, and must be overcome. If the apparatus wearer is breathing fast he cannot overcome the resistance and obtain sufficient air before he starts to exhale. When this condition arises the wearer begins to suffer from "air hunger." This in turn induces a suffocating feeling and the tendency is to remove the breathing-device at all costs. When wearing a breathing-device of any make or type DEEP, SLOW BREATHING IS ESSENTIAL and can only be attained

(*PSI—pounds per square inch)

by continual practice both with or without apparatus. This phase of mine rescue training cannot be overemphasized.

Gas Masks for Protection against All Gases, Smokes and Vapours in Air Containing Sufficient Oxygen to Sustain Life

In its investigations of gas masks for use in mining and allied industries the U.S. Bureau of Mines has studied and developed various types of masks for protection against noxious gases and fumes that may be present in atmospheres found in mines, metallurgical works, chemical and other industries. As a result of these investigations the Bureau issued a schedule of tests under which manufacturers may submit masks for approval. In this schedule masks are classified by the type of gas removed, as follows: A, acid gases; B, organic vapours; C. ammonia; D. carbon monoxide; E, Smoke, dust and mist; F, special gases, (e.g. Hydrocyanic acid used for fumigating); N, all gases, vapours and smokes. Each type carries an approval number which identifies it and its limitations. Each type of canister is distinctively coloured.

The The Carbon Monoxide Self-rescuer and Type N gas mask should be the only types of canister masks used underground in mines.

TYPE N MASK

There have been improvements in the design of the Type N mask from time to time. It is in use at Ontario Mine Rescue Stations under various trade names (Figs. 15 and 16) and carries the approval number of the U.S. Bureau of Mines. It may be identified by an approval plate bearing the seal of the U.S. Bureau of Mines and the approval number on the gas-mask case. The can-

ister also has a label bearing the seal and approval number. The canister is coloured a solid RED.

The essential parts of a Type N gas mask consist of a facepiece attached by a flexible, tube to a check valve connected to the top of a canister containing the chemicals for purifying the air. The canister is held in a harness supported by a strap around the body.

Fig. 15—M.S.A. Type N Mask.

Facepiece

The facepiece forms a pocket for the face and permits breathing through the nose or mouth. It is comfortable to wear, and the wearer can easily carry on a conversation with a person nearby or over a telephone, although

the voice is somewhat muffled and does not carry far. A corrugated-rubber tube, flexible but non-kinking under normal use, carries the inhaled air from the canister to the facepiece. The inhaled air is drawn into the facepiece through tubes which discharge against the lens. The air is

Fig. 16—Willson Type "N" Mask.

dried in passing through the canister, and this prevents serious fogging of the lens. The lens is made of plastic or hardened glass which does not shatter if broken. Exhaled air passes out through a check-valve. Rubber headbands hold the facepiece firmly against the face. These are adjustible so that the facepiece can be made to fit almost any person.

Canister

Fig. 17 shows two models of Type N canisters used in Ontario. They have been found to give satisfactory protection within their limits against the gases and smokes encountered in mine fires. They are not proof against the toxic smokes of modern warfare nor of fires involving certain plastics or chemicals.

Figs. 18 and 19 show the detail of the canisters in use at the mines, with the arrangement of absorbent materials. The case is of metal. The canisters vary slightly in shape and are about 15 square inches in cross-sectional area and 7 inches in height. The recently-developed Window Indicating Canister, Fig. 17 (a) and (b) does not contain any valves, and an external check-valve (c) is used to connect the top of the canister to the breathing tube. A dome-shaped screen above the bottom opening supports the materials and allows a ready distribution of the incoming air over the entire cross-section. The granular absorbents are of 8- to 14-mesh in size, and are placed in horizontal layers in the canister so that all inhaled air passes through each layer of the absorbent. The layers of material are separated by screens, and the whole is held in place by a retaining spring at the top.

Poisonous gases are removed or eliminated from the air passing through the canister in the following manner:—

1. Acid gases such as chlorine, hydrogen sulphide, and sulphur dioxide are removed by chemical combination with the caustic (caustite, limite, etc.).

(a) (b) (c)

Fig. 17—(a) and (b) Type N Canisters
(c) External Check Valve

2. Organic vapours such as acetone, aniline, benzine, chloroform, formaldehyde, and gasoline are absorbed in the charcoal or carbon.

3. Ammonia gas is absorbed in the carbon and silica gel.

4. Carbon monoxide gas is oxidized by the oxygen in the air to carbon dioxide through the catalytic effect of the Hopcalite. The Hopcalite is placed above the other absorbents so that a minimum of moisture reaches it.

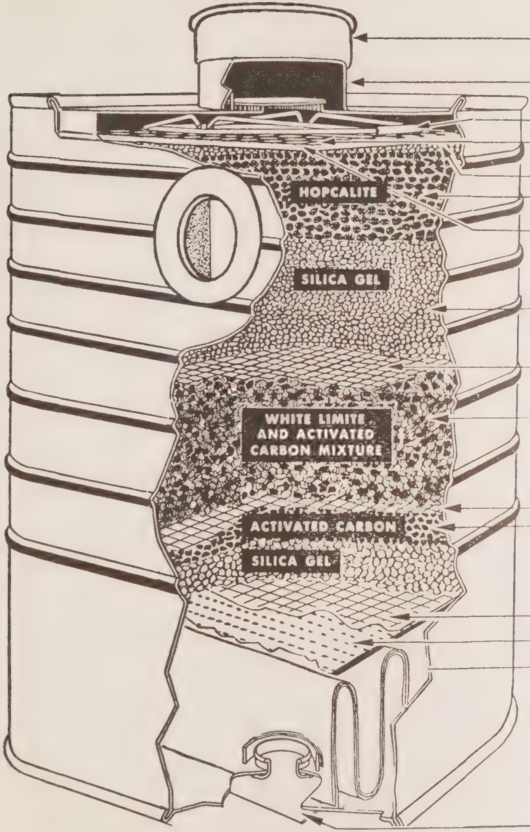
5. The purpose of the calcium chloride in the canister is to remove water vapour from the air, as moisture destroys the efficiency of the Hopcalite. The Window Indicating Canister, (Fig. 17) contains a small round window in the front of the canister, behind which are two color panels. The left panel is dark blue and the right is light blue. When sufficient moisture penetrates the Hopcalite to render it ineffective against carbon monoxide, the dark blue panel will have faded to and matched the light blue color. Continued use will cause it to turn pink.

6. Smoke, dusts and mists are removed by a filter. The specifications of the U.S. Bureau of Mines call for 50 per cent. filtering efficiency against smoke. In service the apparent filtering efficiency is considerably higher.

The canister thus provides protection against all classes of poisonous gases, vapours, and smokes and can safely be used in most places where respiratory protection is needed. HOWEVER, THE IMPORTANT PRECAUTION OF NEVER ENTERING AN ATMOSPHERE CONTAINING LESS THAN 16 PER CENT. OF OXYGEN OR TOTAL CONCENTRATIONS OF POISONOUS GASES EXCEEDING 2 PER CENT. (3 PER CENT. FOR AMMONIA) MUST ALWAYS BE OBSERVED.

Various other type of canisters, some of which are also approved, are used for different gases, vapours, and smoke

Universal Canister, Part No. N2W for Style WUG-N2W & WUGS-N2W Universal Gas Masks



TOP SEAL—	Seals top of canister from external contamination and moisture when not attached to mask.
NOZZLE—	Threaded male fitting for connection to check valve.
RETAINING SPRING—	Exerts constant pressure on canister ingredients, maintains them in proper position.
CHEMICAL RETAINER—	Supporting screen for spring and backing for top dust filter.
CALCIUM CHLORIDE—	Absorbs any moisture accidentally entering top of canister.
HOPCALITE—	Converts carbon monoxide into harmless carbon dioxide. Also absorbs ammonia and various acid gases.
DUST FILTER—	Removes dust and retains chemicals.
SILICA GEL—	Ammonia absorbent, and drier for hopcalite; also absorbs some organic vapors.
REINFORCING SCREEN—	Aids in maintaining chemicals in proper position.
WHITE LIMITE AND ACTIVATED CARBON MIXTURE—	Absorbs acid gases, organic vapors and some moisture.
REINFORCING SCREEN—	Keeps chemicals in proper position.
ACTIVATED CARBON—	Organic vapor absorbent; also absorbs some acid gases, such as chlorine and phosgene.
FILTER CLOTH AND REINFORCING SCREEN—	Retains chemicals above screen and protects smoke filter. Screen maintains chemicals in proper position.
PERFORATED SCREEN—	Support for canister ingredients.
MECHANICAL FILTER—	Removes toxic smokes and provides protection against toxic dusts, fumes, mists and fogs.
BOTTOM SEAL—	Adhesive tape and plug seals bottom of canister from external contamination and moisture when canister is not in use.

Fig. 18—Section through Willson Universal Canister

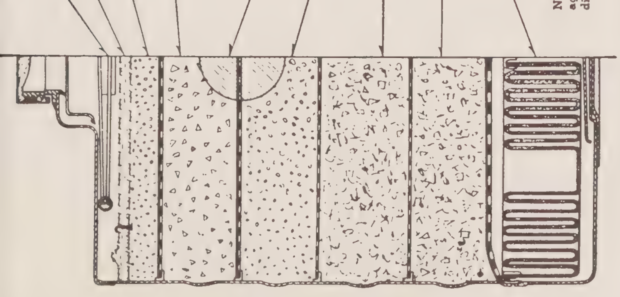


Fig. 19—Section through M.S.A. Type N Canister. Window Indicator.

or combinations thereof, but these canisters do not protect the wearer against carbon monoxide. To identify canisters for different gases and combinations of gases, they are painted certain colours or combinations of colours to indicate the gas or gases against which they afford protection These canisters may be yellow, green, brown, black, white. etc., some are painted one colour with a stripe of another colour. THE TYPE N CANISTER IS RED, AND, AS IT IS THE ONLY ONE THAT PROTECTS AGAINST CARBON MONOXIDE, NO CANISTERS OTHER THAN RED ONES SHOULD BE USED IN MINES DURING OR AFTER A MINE FIRE OR EXPLOSION.

Harness

The harness supports the canister upon the wearer's chest. An adjustable strap around the wearer's neck supports the weight of the canister. Another adjustable strap passes around the body and holds the canister firmly against the chest.

Weight

The weight of the complete equipment is 5¾ pounds; the canister weighs about 3½ pounds. A convenient handcase for carrying the equipment contains a spare canister. The case and contents weigh approximately 14½ pounds.

Procedure for Testing, Adjusting, and Wearing Type N Mask

1. Before wearing a gas mask, carefully examine the various parts to ascertain that the mask is in wearable condition. The canister should be fresh and the bottom seal in place. The rubber parts should be elastic and the eyepieces clean and in good condition. If the Window Indicating canister is used, be sure the external check valve is installed between the breathing tube and the canister. Examine the window to be certain a noticeable difference in colour appears in the papers beneath it.

2. Connect the facepiece tube to the canister with check valve attached. Be sure the gaskets are in place and the connections tight.

3. Pass the head through the loop of the neck-strap, thus suspending the mask from the neck and shoulders.

4. Pass the body-strap around the body, adjust it, and hook the snap in the ring.

5. Hold the facepiece in front of the face, grasping it by the elastic straps in both hands, with the thumbs on the inside.

6. Push the chin well into position in the facepiece, then pull the elastic straps over the head as far as possible and adjust them until a snug fit is obtained. Tighten the straps of the head-harness in the following order: first, the two bottom straps, then the two centre straps, and finally the top straps.

7. With the seal over the bottom opening of the canister still in place, inhale gently and hold the breath. If the facepiece is properly adjusted and all the parts of the mask are tight the facepiece will collapse against the face, indicating that the mask is tight and that no air can enter from the outside. Remove the seal from the bottom of the canister and the mask is ready to be worn in poisonous gases.

8. A LIGHTED FLAME SAFETY LAMP MUST BE CARRIED wherever gas masks are worn, to indicate that oxygen is present to support life. Gas masks should not be used where a flame safety lamp will not burn nor where it would be dangerous to use the lamp.

Laboratory Tests of Type N Masks

Canisters have been tested at rates of air flow of 32, 64, and 85 litres per minute to correspond to the breathing-rates of a man doing various types of work. An air flow of 32 litres per minute corresponds to vigourous work, such as brisk walking at a rate of 3½ miles per hour,

and 64 litres per minute is the maximum rate of breathing of a large man doing more strenuous work such as sprinting. Tests were made at the higher rate of 85 litres per minute continuous flow, because a man inhales only part of the time of the breathing-cycle, and the momentary rates may be higher than the continuous rates employed in testing canisters.

Life of Canisters for Different Gases

When poisonous gases, *with the exception of carbon monoxide* pass successively into the canister, a portion of its life's capacity for absorbing each gas is expended. As the end of the life of a canister approaches, a very small quantity of poisonous gases will pass, and will be detected by the sense of smell or irritation of the eyes, etc. This condition will gradually increase, and will serve as a warning to retreat.

The passage of pure, dry air does no harm to the life of the canister against any gas except carbon monoxide. The various absorbents fail only when saturated with gas or vapours to the point where they can no longer retain all the gas that enters. THE LIFE OF A CANISTER FOR PROTECTION AGAINST CARBON MONOXIDE IS SHORTENED BY THE PASSAGE OF AIR, REGARDLESS OF WHETHER OR NOT POISONOUS GAS IS PRESENT, BECAUSE WATER VAPOUR IS ALWAYS PRESENT IN THE AIR AND THE HOPCALITE FAILS TO FUNCTION WHEN THE MOISTURE FINALLY SATURATES IT. Because of the presence of carbon monoxide, the length of time that a standard canister can be safely used has been set at 2 hours. The window-indicating canister may be safely used for protection against carbon monoxide until the dark blue indicating color fades and corresponds to the light blue color beside it. As carbon monoxide cannot be detected by the senses a canister

must be discarded before actual penetration can occur. All other poisonous gases can be detected by odour, taste, or eye irritation. When penetration of any gas is detected the wearer must go to fresh air immediately, and the canister must be exchanged for a new one whether the 2-hour time limit has elapsed or not. The penetration is very small at first, and the decrease in efficiency of the canister is gradual. The wearer of a mask thus has plenty of time to escape before a dangerous amount of gas passes. Mixtures of all the poisonous gases are not often encountered, and in such a mixture one poisonous gas is usually predominant. For instance, during fires or after explosions distillation products of wood containing ammonia and organic vapours may be found; sulphur dioxide may be present, but carbon monoxide always constitutes the major hazard. The canister of the Type N mask will protect the wearer when the total of the poisonous gases does not exceed 2 per cent.

High Resistance or High Temperature in Canisters

It is not likely that gas masks will be used under conditions other than those specified in the approval because the heat and resistance of a canister to breathing usually increases to an intolerable point before any carbon monoxide penetrates as far as the facepiece. The reason is that carbon monoxide in excess of 2 per cent. will cause so much heat to be generated by the chemical reaction that the inspired air will be intolerable to the wearer. More than 2 per cent. of carbon monoxide is rarely encountered where a flame safety lamp will burn. A lighted flame safety lamp should always be carried where masks are being worn.

Use of Type N Masks for Recovery Work

The Type N gas mask is used to a considerable extent in fighting mine fires and for operations after explosions.

A considerable percentage of the work in irrespirable atmospheres may be done by men wearing gas masks, with self-contained oxygen or air breathing-apparatus teams in reserve.

Precautions When Using Type N Masks

1. Use gas masks only where a flame safety flame will burn and where it is safe to use the lamp.

2. If the flame safety lamp is extinguished, return to fresh air immediately.

3. Do not exceed the approved service time of two hours for a non-window type canister.

4. Do not use any other than Type N canisters with the approved facepieces. These canisters are all painted solid RED.

5. Standard canisters without windows may be used intermittently for a total life of 2 hours over a period of one year if they are kept sealed when not in use. At the end of one year after unsealing they should be discarded, whether or not they have been completely used. It is emphasized that the canister should be dated when the seal is first broken. Space is provided on all canisters for this purpose. IN MINE RESCUE AND RECOVERY OPERATIONS ALWAYS USE A FRESH CANISTER.

6. The complete gas mask should be carefully examined and tested for tightness and proper adjustment by the wearer before it is worn in a poisonous atmosphere.

7. When the Type N mask is worn, whether in training or actual use, the wearer will find that it is to his advantage to learn the art of slow, deep breathing even when doing strenuous manual labour. Slow, deep breathing should be practised until it becomes a habit. Continual practice with the mask and canister is the only teacher. When penetration of any gas is detected the wearer must go to fresh air immediately, and the canister must be

exchanged for a new one even though the 2-hour period of use has not elapsed.

Limitations of Use

THE LIMITATIONS OF USE OF THE TYPE N MASK IN AIR ARE EXCEEDINGLY IMPORTANT. GAS MASKS DO NOT SUPPLY THE OXYGEN NECESSARY TO LIFE; THEY CAN ONLY REMOVE RELATIVELY SMALL PERCENTAGES OF POISONOUS GASES FROM AIR. Normal air contains nearly 21 per cent. of oxygen. WEARERS OF MASKS SHOULD MAKE SURE THAT 16 PER CENT. OR MORE OF OXYGEN IS PRESENT IN THE AIR. This may be determined by means of a flame safety lamp. As long as the flame burns there is enough oxygen for a man to breathe, as the flame will go out when less than 16 per cent. of oxygen is present. The gas mask does not provide protection in covered tanks or other confined spaces, in vaults or cellars without ventilation, or in unventilated wells, shafts, pits, or parts of mines where fires or explosions may have consumed the oxygen, or where large quantities of poisonous or asphxiating gases or vapours may have been formed. Because of the dangers of oxygen deficiency in the atmosphere, the necessity of caution in the use of gas masks cannot be too strongly emphasized. In such deficient atmospheres, self-contained breathing-apparatus, which provides complete protection, must be used.

For the above reasons the approval of the Type N gas mask is limited to respiratory protection in mine atmospheres where a flame safety lamp will burn, in air that contains acid gases, organic vapours, or carbon monoxide not exceeding 2 per cent. by volume, in atmospheres containing not more than 3 per cent. of ammonia, in smokes, dusts, and mists, or in atmospheres not containing a total of more than 2 per cent. of poison-

ous gases when more than one gas is present. Although the Type N gas mask protects against carbon monoxide or other gases anywhere a flame safety lamp will burn, the lamp can not safely be used in explosive mixtures of methane, hydrogen or acetylene. Fig. 16 shows a man wearing a gas mask and carrying a lighted flame safety lamp.

CARBON MONOXIDE SELF RESCUERS

Filter Type (Figs. 20-21-22)

General

Filter CO respirators, commonly called "Self-Rescuers" are one-time-use devices FOR ESCAPE PURPOSES ONLY. The three types described here are the MSA W. 65, Auer CO filtering Self-Rescuer No. 101, and the Drager FSR 810. The rugged construction of these appliances allows them to be carried by personnel while at work or they may be mounted on mobile equipment ready for instant use. Used under these conditions they are normally approved for only a five-year period after which time they must be replaced with new units. However, when kept properly in storage they have an indefinite shelf life. Training models of all types are available. Carbon Monoxide self-rescuers do not give protection against any other noxious gas nor from a deficiency of oxygen. The presence of carbon monoxide will be indicated by heat generated in the self-rescuer. All three types have been approved by the U.S. Bureau of Mines and will provide adequate protection for sixty minutes in one percent concentration of carbon monoxide. At two percent carbon monoxide concentrations, the heat generated by the chemical reaction of the hopcalite will be almost unbearable, yet the hopcalite will still function and provide adequate protection to the wearer. All units have a built-in heat exchanger to help reduce the temperature of the air reaching the wearer's mouth.

The self-rescuer MUST be kept on and used, regardless of the heat generation.

Description MSA. W. 65 (Fig. 20)

This unit comes enclosed in an easily-opened, hermetically sealed stainless steel case. The entire unit weighs 2.2 lbs. It consists of an outer coarse-dust filter and an inner fine-dust filter for the removal of solid particles suspended in the atmosphere, a charge of hopcalite and a drying agent to protect the hopcalite from moisture which would destroy its ability to oxidize carbon monoxide. The rubber mouthpiece contains a saliva drainer to prevent moisture from reaching the filtering chemicals. The nose clip prevents breathing through the nose and is attached to the device by a cord. The self-rescuer is held in the wearing position by an adjustable cradle-type head harness.

To Use

1. Pull the red lever up hard to break the seal. Remove the top cover and discard.
2. Pull mask from case.
3. Insert mouthpiece between lips and teeth, bite on the lugs. Adjust head harness to support respirator. Adjust nose clip on nose.
4. BREATHE ONLY THROUGH THE SELF RESCUER.

AUER 101

This appliance is almost identical to the MSA W. 65 but has advantages of design that make it possible to strip and recharge, or repair it rather than having to discard it after five years of non-operating service. It also incorporates a test nipple that facilitates air tightness tests so that the unit may be opened, checked, and re-sealed. The coarse filter bag is held in place by a coil tension spring so that it may be easily slipped off should it become clogged. Pro-

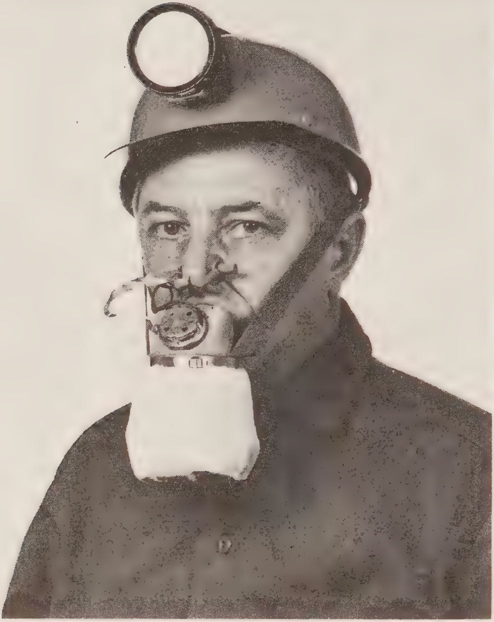


Fig. 20—Man Wearing MSA W-65 Self-Rescuer.

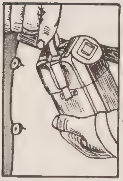
cedure in using this self-rescuer is the same as with the MSA model.

DRAGER MODEL FSR 810 (Fig. 22)

The Drager filter self-rescuer is enclosed in an hermetically sealed plastic case carried in a soft vinyl carrying pouch. The filter consists of a coarse dust filter bag with a fine dust filter in the bottom. A layer of drying agent below the hopcalite absorbs moisture from the inhaled breath.

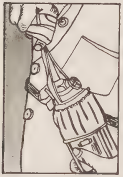
Self-Rescuer® respirator.

instructions for use.



1 OPEN

pull Red Lever up hard to break seal. remove cover and discard.



2 REMOVE

pull mask from case. discard bottom of case.

3 TO USE

insert mouthpiece between lips and teeth, bite on lugs. place nose clip over nostrils. pull support strap over head. breathe thru Self-Rescuer.

Fig. 21—Self-Rescuers—Instructions for Use.

The dried air then passes through the hopcalite which converts any carbon monoxide to harmless carbon dioxide. A mesh of fine wire dissipates the heat generated by the reaction of carbon monoxide and the hopcalite. Exhaled breath passes out through a spring-backed mica exhalation valve. A rubber nose clip prevents breathing through the nose when the rubber mouthpiece is in place. A webb headstrap supports the mask while in use.

To Use

Remove from the carrying pouch and break the seal by raising the lever on the top of the case.

Discard the top half of the case and pull the mask out of the bottom half.

Insert the mouthpiece between the lips and teeth and hold in place by biting on the rubber lugs.

Adjust the nose clip and head harness. BREATHE ONLY THROUGH THE SELF-RESCUER.

Fig. 22—Drager FSR 810 Being Opened.

Self-contained Oxygen Breathing-apparatus

Physiological Effects of Breathing Pure Oxygen

Many persons believe that the breathing of pure oxygen is dangerous to health, that it "burns up" the person who breathes it. The quantity of oxygen consumed

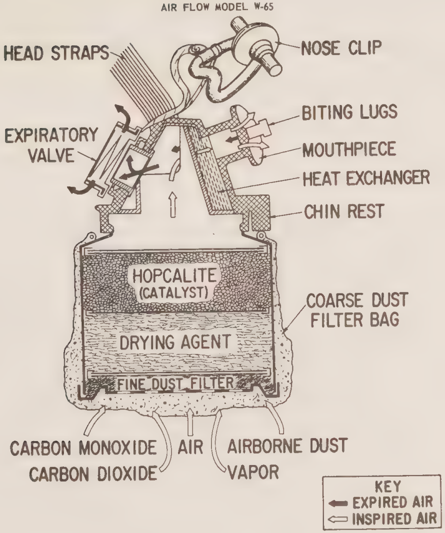


Fig. 23—Diagrammetic Sketch of MSA W-65.

by the body varies with the amount of exertion expended. A man at rest consumes approximately 16 cubic inches of oxygen per minute. During violent exercise the consumption may increase to more than 8 times that amount. The body consumes no more oxygen than it requires.

The pure oxygen breathed by the wearer of a self-contained oxygen breathing-apparatus causes no noticeable ill effect, even after several successive periods of use, unless the wearer is subjected to air pressures in excess of the normal atmospheric pressure of 14.7 psi., such as might be encountered in caisson work.

"The Elimination of Dangerous Amounts of Carbon Dioxide in the Circulatory System of the Apparatus."

One of the most important functions of any closed-circuit self-contained oxygen-breathing apparatus is the elimination of dangerous amounts of carbon dioxide from the circulatory system of the apparatus.

In early types of apparatus, this elimination was usually accomplished by passing the exhaled air over sodium or

Fig. 24—Miner Wearing Drager BG174 Apparatus

potassium hydroxide held on trays in the regenerator, or loose in the bottom of the breathing-bag.

In the Chemox apparatus, this absorption takes place in a canister where oxygen is generated simultaneously by chemical action.

In demand-type apparatus using compressed pure air, the exhaled air passes through a valve to the outside atmosphere.

In the Drager BG174 apparatus, two methods of carbon dioxide removal are in use, (1) a disposable alkaline cartridge, and (2) a re-fillable soda-lime canister in which materials known under the trade names of Cardoxide, Safe-T-Sorb or Drager-Sorb may be used.

The alkaline cartridge has two advantages over the second method, (a) a four-hour duration, and (b) more efficient moisture removal.

The Drager Self-contained, Oxygen-breathing Apparatus Type BG174—Fig. 24.

I. GENERAL DESCRIPTION

1. The Drager self-contained oxygen-breathing apparatus, carried on the back enables the mine rescue worker to enter underground areas filled with irrespirable and toxic gases. The apparatus permits the wearer to breathe completely independent of the atmosphere and enables him to effect rescue and recovery in extremely arduous conditions.

2. This closed-circuit apparatus is light in weight (28 lbs.), but its construction is rugged and highly resistant to mechanical shock. The exhaled air is freed of its carbon dioxide content in a regenerative canister and passed into a breathing bag. The air purified in this way is then withdrawn from the breathing bag during inhalation.

3. The oxygen consumed during respiration is replaced from a compressed oxygen supply through constant-flow metering at the rate of 1.5 litres per minute and, if this is not sufficient to supply the wearer, additional oxygen is provided by a lung-governed demand valve.
4. When the apparatus is initially turned on, the circuit is automatically flushed with approximately 6 litres of oxygen. Apart from the occasional checking of a pressure

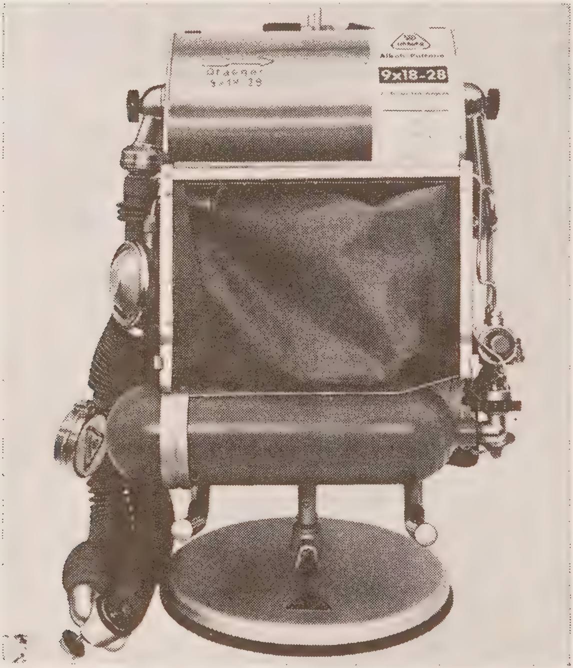


Fig. 25—BG174—opened, on stand

gauge, the apparatus requires no further attention during its use. Its operating functions are entirely automatic.

Description of Parts—(Fig. 26).

The apparatus consists of six main, and a number of auxiliary parts. (1) oxygen bottle, (2) oxygen control assembly, (3) valve assembly, (4) breathing tubes and facepiece, (5) regenerative canister, (6) breathing bag.

Auxiliary parts include frame, harness, cover, gauge tube and gauge.

1. *The Oxygen Bottle* is a high-grade alloy steel cylinder with an atmospheric volume of 2 litres. When charged to a pressure of 2000 pounds, it contains approximately 270 litres, and at its maximum pressure of 3000 pounds, it will contain approximately 400 litres of oxygen. The bottle must be hydrostatically tested every five years to comply with the regulations of the Ministry of Transport, Canada. The testing pressure is 4400 pounds per per square inch.

   The bottle valve is equipped with a safety cap designed to permit the escape of oxygen without rupturing the bottle under excessive pressure (4000 lbs.)

2. *The Oxygen Control Assembly* is made of brass and is attached to the right-hand wall of the carrying frame. It contains the reducing valve, the pre-flushing unit, the manual by-pass valve for an emergency oxygen supply, and the valve for the pressure gauge line. This assembly is directly coupled to the oxygen bottle by a hand-tight connection.

3. *The Valve Assembly* attached to the left-hand wall of the frame, controls the delivery of oxygen to the wearer, and consists of a metering orifice designed to allow a constant flow of 1.5 litres per minute. Also included in the assembly are a demand valve to provide additional

oxygen if required, inhalation and exhalation valves, a warning device, pressure relief valve, check valve and connections for the breathing tubes.

4. *The Breathing Tubes and Facepiece.* The tubes are of corrugated rubber with a central connection to attach the facepiece, and with individual couplings connecting to the valve assembly. A moisture trap is attached to the inhalation tube.

   The facepiece has a curved full-view lens with a manually-operated wiper. The neoprene mask body has an inner face-seal and is held in place by a five-strap quick-adjusting head harness.

5. *The Regenerative Canister* in which carbon dioxide is removed from the exhaled breath may be one of two types: a disposable alkaline cartridge which may be used for a continuous period of up to four hours: a refillable canister which may be used for a maximum period of two hours.

   The use of the alkaline cartridge provides drier breathing air. The wearer is therefore under less physical stress than when using the refillable canister.

6. *The Breathing Bag* is made of 3-ply rubberized fabric. It is so arranged within the carrying frame that it is protected on all sides, but is able to function without obstruction. It contains a coupling for the valve assembly connection and an elbow connection to the regenerative canister. The minimum capacity of the breathing bag is 6 litres.

Auxiliary Parts

1. *The Carrying Frame and Harness.* The frame is made of corrosion-resistant light alloy. The flat side walls, together with the curved plates of the regenerative canister support at the top, and the cylinder support at the bottom constitute a torsion-resistant frame. The

back plate acts as a protective cover for the breathing-bag space. All fittings of the apparatus are attached to the strong side walls. The regenerative canister support is so arranged that the canister itself is properly cooled, and the transfer of heat to the back of the wearer by conduction and radiation is minimized.

The rear of the frame is provided with a resilient pad of rubberized fabric with a steel insert, ensuring a comfortable fit, and proper spacing of the apparatus from the body of the wearer.

The harness is made of nylon-cotton fabric, is comfortable to wear, and is easily adjusted.

2. *The Cover* protects the components of the apparatus when in use, and is easily removable.
3. *The Gauge Tube and Gauge.* The tube is a rubber-covered, high pressure, flexible, close-wound spiral hose. The clear, easily-read pressure gauge is fitted with a swivel connection to facilitate correct positioning.

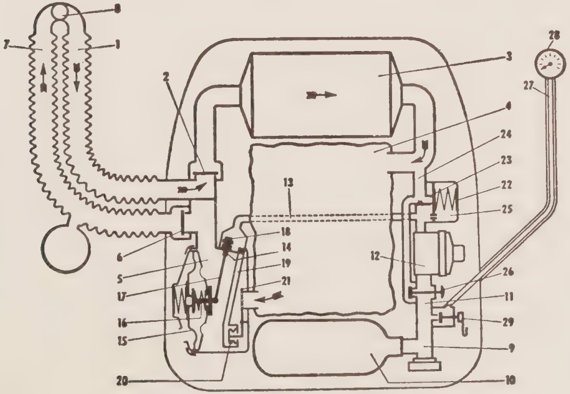


Fig. 26—Circuit of the BG174

Function of the Apparatus—(Fig. 26)

1. exhalation tube
2. exhalation valve
3. regenerative canister
4. breathing bag
5. valve assembly
6. inhalation valve
7. inhalation tube
8. facepiece connection
9. bottle valve
10. oxygen bottle
11. oxygen control assembly
12. reducing valve
13. oxygen line
14. metering orifice
15. control diaphragm
16. relief valve
17. demand valve lever
18. demand valve seat
19. bellows line
20. warning signal bellows
21. warning signal flap
22. pre-flush unit
23. pre-flushing control valve
24. pre-flush and by-pass line
25. diaphragm chamber
26. manual by-pass valve
27. pressure gauge tube
28. pressure gauge
29. gauge valve

Closed Circuit Operation (see Fig. 26).

The exhaled air containing carbon dioxide flows from the mouth through the exhalation tube (1), to the exhalation valve (2), and then to the regenerative canister (3), where the carbon dioxide is absorbed. The absorption process is accompanied by the production of heat, increasing the temperature of the canister and the air flowing through it. The air, freed of carbon dioxide, and respirable then flows into the breathing bag (4).

During inhalation, the air is drawn from the breathing bag and flows through the valve assembly (5), to the inhalation valve (6), the inhalation tube (7), to the facepiece connection (8). The air within the apparatus is thus continuously inhaled and exhaled in a closed circuit. Its direction of flow is controlled by valves (2) and (6) in the valve assembly.

Constant-Flow Metering

In normal operation, the oxygen consumed during respiration is replaced by constant flow-metering at the

rate of 1.5 litres per minute. With the bottle valve (9) open, high pressure oxygen flows from the bottle (10), to the reducing valve (12), located in the oxygen control assembly (11). The oxygen pressure is there reduced to a pressure of 57 p.s.i. at which it flows through the oxygen line (13), the metering orifice (14), and into the valve assembly (5) where it replenishes the closed-circuit air.

Relief Valve

If the oxygen consumption is less than the supply through the constant-flow-metering system, the breathing bag becomes over-inflated during exhalation. The excess pressure thus produced in the breathing bag causes the control diaphragm (15) in the valve assembly (5) to move to the left against a spring. An orifice in the centre of the diaphragm is equipped with a sealing lip which is lifted off a sealing plate, enabling the excess air to flow through the diaphragm and escape through a non-return valve to outside air.

Automatic Demand Valve

Under conditions of extreme physical effort, the oxygen requirement may exceed that supplied by constant-flow-metering. In such circumstances the breathing bag fills to a progressively smaller degree with each breathing cycle until finally its contents no longer supply the wearer with oxygen. A negative pressure is then created which immediately moves the diaphragm (15) of the valve assembly (5) to the right. The sealing plate of the relief valve is then actuated so that a plunger pushes the lever (17) of the demand valve (18) to the right, opening the valve. Oxygen then flows through the oxygen line (13) into the valve assembly (5) and into the inhalation chamber until the requirements are again fully met.

Warning Signal

The oxygen line (13) is provided with a bellows line (19) in the valve assembly (5) leading to the bellows (20). The control bellows is hinged by a double-arm lever to the warning signal flap (21). This flap covers the breathing bag connection in the valve assembly (5) when the apparatus is not under pressure. If an attempt is made to breathe while it is without pressure, the air drawn from the breathing bag passes through slits in the flap covered by acoustic reeds. A clear musical note is then heard, warning the wearer that the bottle valve has not been opened.

As soon as the bottle valve is opened and the oxygen line (13) pressurized, oxygen flows through an orifice to the bellows, compressing it so the warning signal flap is moved away from the breathing bag connection.

Pre-Flushing

When the oxygen bottle valve is opened, oxygen flows through the reducing valve (12) to the pre-flushing unit (22). The pressure opens the control valve (23) so that oxygen flows through the pre-flushing line (24) into the circuit and fills the breathing bag. Simultaneously, oxygen flows through an orifice into the diaphragm chamber (25) of the pre-flushing unit. As soon as pressures are balanced on each side of the diaphragm, the valve (23) is closed by spring pressure, thus completing the pre-flushing process. The pre-flushing unit functions so that a minimum of 6 litres of oxygen flows into the apparatus.

Manual By-Pass Valve

Depressing the button of the manual by-pass valve (26) causes oxygen to flow from the high-pressure side of the oxygen control assembly directly to the pre-flushing line (24) and from there into the circuit. This emergency

oxygen supply is thus independent of the reducing valve, the demand valve and the constant-flow-metering orifice.

Pressure Gauge and Gauge Tube

The gauge tube (27) branches from the high pressure side of the oxygen control assembly. The pressure gauge (28) is provided with luminous markings on the dial and pointer so the bottle pressure can be constantly checked even in complete darkness.

The gauge tube may be closed by a valve (29) in the event of a leak in the tube or gauge.

II. FIELD TESTS

THESE TESTS SHOULD ALWAYS BE MADE IMMEDIATELY BEFORE THE APPARATUS IS USED. This assures the wearer that the apparatus is fit for use without taking the word of any other person. Should the wearer not be satisfied that such is the case, he should report to the person in charge and not "get under oxygen"

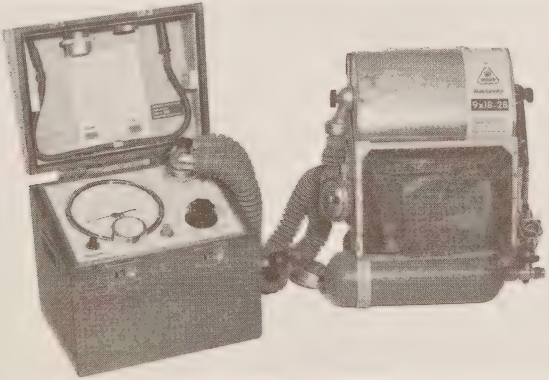


Fig. 27—Testing BG 174 with Rz 25 Tester.

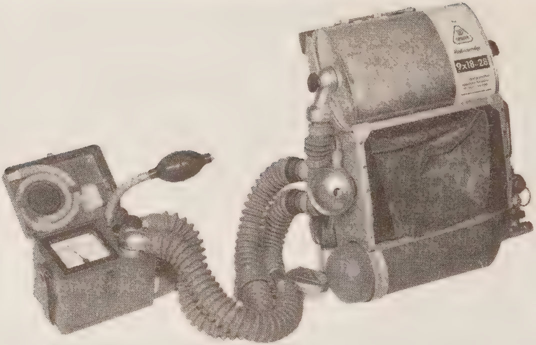


Fig. 28—Testing BG 174 with Rz 35 Tester.

until the apparatus is to his satisfaction. These field tests have been devised to give him that assurance.

With the aid of the Drager Apparatus Testers (see figs. 27 & 28), and without spending much time, the operator can ascertain his apparatus is fit to wear by means of four simple tests. These tests, for the greatest efficiency, should be carried out in the same order as they appear below.

See that all the necessary items of equipment are present and complete.

1. *Bottle Pressure and Pre-Flush*

Lay the apparatus on its cover, examine the harness, remove the gauge from its protective cover and open the bottle valve. When the pre-flushing is completed, observe the pressure on the gauge. Close the bottle valve, observe the gauge needle slowly dropping towards zero. Press the by-pass valve and reduce the pressure to zero.

2. *Regenerator Test*

Lay apparatus on its harness and remove the cover (fig. 29).

A. When using the alkaline cartridge:—Remove the seal and blank ends from the cartridge. Make certain the gaskets of the connections are in good condition, insert the cartridge into its support, with the arrow in the proper direction and tighten the connections firmly.

B. When using the re-fillable canister:—Be certain it is completely filled by thoroughly shaking and topping it up. Check the filler plug and gasket, replace plug and tighten. Insert canister into its support and tighten connections firmly.

3. *Negative Pressure Test (Using Rz 25 or Rz 35 Testers)*

Fig. 29—Removing Cover of the Apparatus

Inspect breathing tubes, moisture trap plug and gaskets. Attach breathing tubes to apparatus and attach the other end of the tubes to a Dräger Apparatus Tester.

(a) With Rz 25 Tester: (fig.27)

Empty the breathing bag by pressing it flat with the hand. Set the selector knob of the tester to "Negative Pressure Pumping" and *gently* operate the pump lever until the needle indicates a vacuum of between -75 and -90 mm. Turn selector knob to "Leak Test", reduce the vacuum to -70 mm. by pressing the red button and observe the needle for 10 seconds. (A pressure drop of 10 mm. per minute is permissable.) Disconnect tubes from tester and replace apparatus cover.

(b) With the Rz 35 Tester: (fig. 28)

(1) Remove the rubber cap from the tester and connect the breathing tube manifold.

(2) Empty the breathing bag by pressing it flat with the hand.

(3) Slide the rubber tube with aspirator attached over the metal pipe protruding from the top of the tester.

(4) Depress and hold the black button to open the control valve, and continue to squeeze the aspirator bulb until the needle reaches the upper limit on the dial.

(5) Release the pressure on the button, bring the needle to the green area of the dial and observe for 10 seconds. Movement of the needle towards zero indicates a leak in the apparatus.

(6) Disconnect tubes from tester and replace apparatus cover.

4. *Facepiece Test*

Examine facepiece and connect to breathing tubes, making certain the gasket is in place. Put on the facepiece and adjust straps. Squeeze both tubes and inhale to test the facepiece seal. Squeeze the tubes individually, inhale and exhale to test valves. Remove facepiece from the face.

Fig. 30—Putting on the Apparatus

Report results of field tests to the team captain when requested.

III. GETTING UNDER OXYGEN

Facepiece lens must be prepared with anti-fog solution.

1. Put on apparatus and adjust straps. (Fig. 30)
2. Open bottle valve fully, close ½ turn and observe pressure on gauge. (Fig. 31)
3. Put on and adjust facepiece.
4. Squeeze both tubes and inhale to test facepiece seal. (Fig. 32).

Fig. 31—Opening the Oxygen Bottle Valve

Getting Out of Oxygen (await order from Captain)

1. Remove facepiece.
2. Close bottle valve and reduce gauge to zero.

Sterilization of Breathing Apparatus

For hygienic reasons the breathing tubes, facepiece and breathing bag of the apparatus should be washed, placed in a sterilizing solution and dried after each period of use. The sterilizing solution may consist of any proven commercial germicide mixed in the proportion recommended by the manufacturer. The valve assembly should be sterilized periodically when in use.

Fig. 32—Checking for Tightness of the Facepiece

IV. STATION TESTS (Using Rz 25 Tester)

1. *Exhalation and Inhalation Valves*

Squeeze the breathing tubes one at a time by hand, and attempt to blow into, and subsequently to draw air from the apparatus. If the inhalation tube is tightly squeezed it should not be possible to draw air through the apparatus. If the exhalation tube is tightly squeezed, it should be impossible to blow air into the apparatus.

2. *Pre-Flushing and Bottle Pressure*

Connect the apparatus to the Type Rz 25 Universal Testing Unit by use of the adapter provided. Empty the

breathing bag by pressing it flat with the hand. Adjust the pointer of the tester to zero if necessary. Open the bottle valve and observe the breathing bag. This should be well filled by the pre-flushing action. Inspect the pressure gauge.

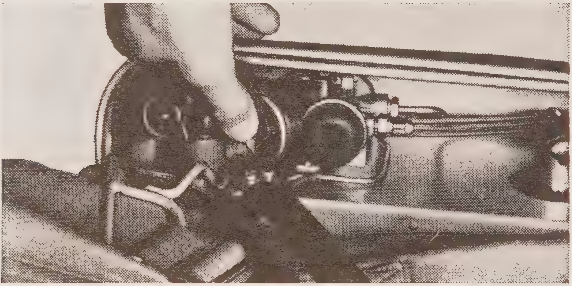


Fig. 33—Using the By-pass

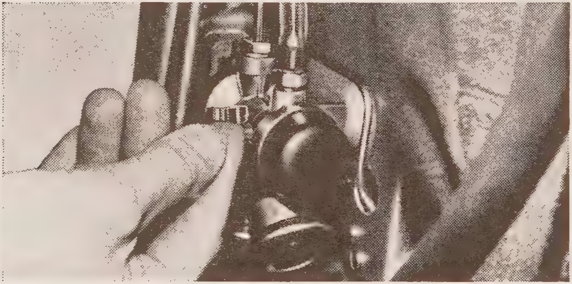


Fig. 34—Operating the Gauge Valve

3. *Automatic Demand Valve*

Set the testing unit to "Negative Pressure Pumping" and pump the breathing bag empty until the demand valve can be heard to function. The warning signal should *not*

sound during pumping. Once again, operate the automatic demand valve by slow pumping, at the same time observing the testing unit. The automatic demand valve should come into action with a vacuum of −15 to −40 mm. WG.

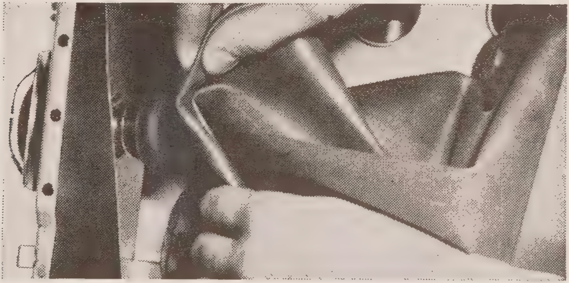


Fig. 35—Removing the Breathing Bag

4. *Manual By-Pass Valve*—(Fig. 33)

Briefly operate the push-button of the manual by-pass valve. There should be an audible flow of oxygen into the circuit. There should also be visible filling of the breathing bag.

5. *Constant-Flow Metering and High-Pressure Leakage Testing*

Seal off the relief valve discharge port in the diaphragm housing by inserting the rubber plug provided. If necessary, fill the breathing bag completely by pumping with the testing unit set at "Positive Pumping Pressure". Then set the testing unit to "Dosage Test" and observe the pointer of the testing unit.

The rate of flow obtained with constant-flow metering should be between 1.4 and 1.7 litres/min. Close the cylinder valve.

6. *Positive Leakage Test*

Leave the rubber plug in position in the relief valve discharge port. Set the testing unit to "Positive Pressure Pumping" and, by operating the bellows, produce a pressure of 80 to 100 mm. Set the testing unit to "Leak Test" and reduce the pressure to 70 mm. The pressure must not fall by more than 10 mm. over a period of one minute. If there is a greater pressure loss, tighten all connections. If this

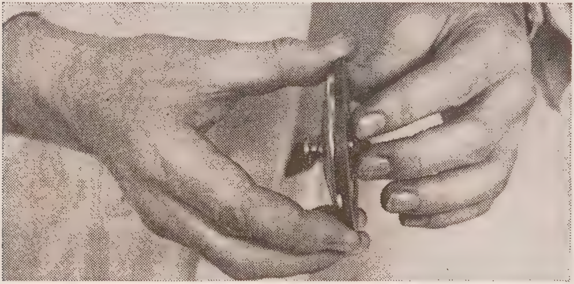


Fig. 36—Checking the Movement of the Diaphragm

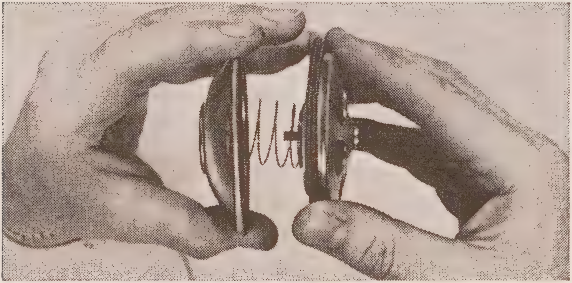


Fig. 37—Inserting the Relief Valve Spring

does not provide the remedy, all individual components must be checked separately for leakage, with emphasis on the breathing bag connection.

7. *Relief Valve*

Remove the plug from the relief valve discharge port. Set the testing unit to "Positive Pressure Pumping" and operate the bellows slowly and evenly. Observe the testing unit.

The relief valve should open at a pressure of between 15 and 40 mm.

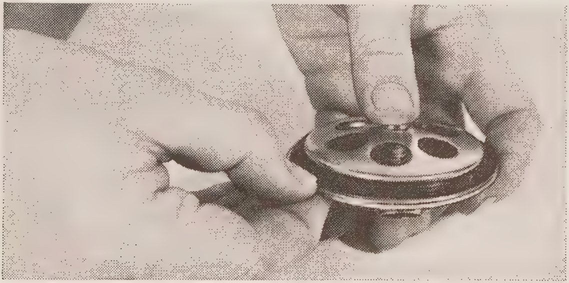


Fig. 38—Fitting the Diaphragm Ring

8. *Warning Signal*

Set the testing unit to "Negative Pressure Pumping" and empty the breathing bag. The warning signal should sound clearly with each pumping stroke.

9. *Negative Leakage Test*

Continue to evacuate the breathing bag until the pointer of the testing unit is located between −80 and −100 mm. Set the tester to "Leak Test" and reduce the pointer to −70 mm. The vacuum should not fall by more than 10 mm. over a period of one minute.

Remove the breathing tubes from the tester and seal the connection with the cap. Replace the cover on the apparatus.

V. MAINTENANCE OF THE APPARATUS

Self-contained oxygen-breathing apparatus should be tested thoroughly every month. The following program should be carried out:—

Thoroughly rinse the breathing bag and breathing tubes with clear, lukewarm water. The rubber components should be kneaded. If there is any alkaline fluid in any part of the apparatus, vinegar should be added to the rinsing water, after which all parts should be rinsed again with clean water. The components should be dried, away from direct sunlight. Compressed air should not be used in drying.

The condition of the valve assembly diaphragm should be checked at least once every year, and changed if any

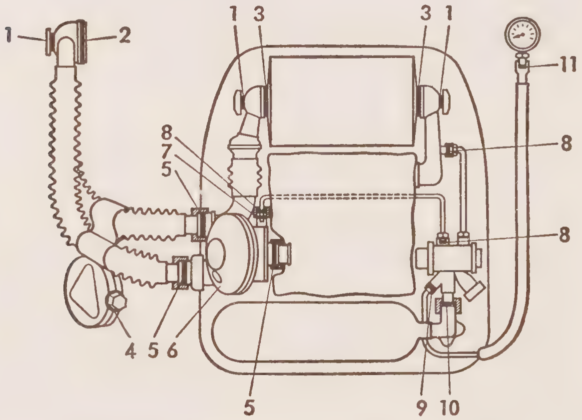


Fig. 39—Location of Gaskets on the BG 174

signs of wear or aging occur. The rubber inhalation valve and the rubber non-return valve of the relief valve should receive the same attention.

Care must be taken that the apparatus does not become damp or dirty in storage. Economies made on inadequate maintenance are lost in the costs of replacements.

Oil or other lubricants must not be used on any oxygen apparatus, particularly involving the high pressure connection or the bottle valve. Failure to observe this precaution may lead to an explosion.

The apparatus must not be stored in direct sunlight nor in hot areas.

Properly sealed alkali cartridges have a shelf life of at least four years without any loss of efficiency. After this period has elapsed, canisters should be used for training purposes.

A record should be kept for each apparatus showing the tests carried out and the test dates. The record should also indicate if the apparatus is stored ready for use.

Questions and Answers on Drager BG174 Oxygen Breathing-apparatus

1. What is the normal pressure in a fully-charged oxygen bottle?

The normal pressure in a fully-charged oxygen bottle is 2000 p.s.i.

2. Why is it necessary to have a pressure gauge?

The pressure gauge indicates the pressure in the oxygen bottle?

3. How would you test for moisture in an oxygen bottle.

Hold the bottle with the valve end down and open the main bottle-valve. If moisture is present, it will show in the form of vapour.

4. How would you test the oxygen bottle and the main bottle-valve for air-tightness?

To test the oxygen bottle and the main bottle-valve for air-tightness, immerse the bottle and valve in water; bubbles indicate leaks. Place a metal cap on the outlet end of the main bottle-valve, open the main bottle-valve, and immerse the valve in water; escaping bubbles will show any leaks around the packing-gland or stem.

5. Why is a safety cap attached to the main bottle-valve?

A safety cap is attached to the main bottle-valve to provide for the escape of oxygen without rupture of the cylinder during exposure to fire. The cap contains a frangible disc that will rupture if the pressure is increased beyond the safety factor of the material.

6. Why does a metal tube project from the end of the main bottle-valve into the oxygen bottle?

A metal tube projects from the end of the main bottle-valve into the oxygen bottle in order to draw out oxygen free from sediment, moisture or rust.

7. Why is the apparatus equipped with a by-pass valve?

The by-pass valve is provided so that the wearer can be supplied with oxygen if some working part of the high-pressure side fails.

8. When the by-pass valve is opened, does the oxygen have a free, open course to the wearer's lungs?

Yes. The oxygen flows from the bottle directly into the pre-flushing line and into the breathing circuit.

9. Is it a good policy to use the by-pass valve when the automatic valves are supplying the wearer with sufficient oxygen.

The by-pass valve should not be used when the automatic valves are supplying sufficient oxygen. Excessive pressure in the breathing circuit will cause loss and wastage

of oxygen to the outside atmosphere through the relief valve.

10. How many turns should the main bottle-valve be opened?

The main bottle-valve should be opened to its fullest extent, and then closed ½ turn.

11. What is the function of the Demand Valve?

To provide additional oxygen to the wearer as required, during periods of increased or excessive work when the constant flow of 1½ litres might not be sufficient.

12. What is contained in the Oxygen Control Assembly?

This unit contains the reducing valve, the pre-flushing unit, the by-pass valve and the gauge valve.

13. What would you do if the gauge-tube developed a leak?

If the gauge-tube develops a leak, close the pressure-gauge valve and return to the fresh air base. It is not necessary to use the by-pass in this case.

14. What is the purpose of the breathing-bag?

The breathing-bag acts as a reservoir for the exhaled air.

15 What is the air-capacity of the breathing-bag?

The air-capacity of the breathing-bag is approximately 6 litres.

16. Why are flexible corrugated-rubber tubes attached to the facepiece?

The tubes allow free movement of the wearer's head and do not interfere with the circulation of air in the apparatus.

17. Why are there inhalation and exhalation valves on a breathing-apparatus?

The inhalation and exhalation valves circulate the air in one direction, so that it can be purified and cooled.

18. How would you test the facepiece?

(a) Examine the rubber parts of the facepiece and corrugated breathing-tubes, paying particular attention to any scuffed or worn spots.

(b) Attach the facepiece to the breathing tube connection, and the breathing tubes to the apparatus. Put on and adjust the facepiece.

(c) Squeeze both tubes and inhale to test the facepiece seal.

(d) Squeeze the tubes individually, inhale and exhale to test the valves. If the inhalation valve is operating, it should not be possible to exhale while squeezing the exhalation tube. If the exhalation valve is operating, it should be impossible to inhale while squeezing the inhalation tube. Any leaks in the facepiece or breathing tubes should be reported and another unit obtained.

19 What percentage of carbon dioxide is given off in exhalation?

Approximately 4 to 6 per cent. of carbon dioxide is given off in exhalation.

20. How many pounds of carbon-dioxide absorbent does a fully-charged apparatus contain?

A fully-charged apparatus contains approximately 6 pounds of absorbent.

21. How would you empty the apparatus and charge it with absorbent?

To empty the apparatus and charge it with absorbent, remove the screw-cap of the regenerator, pour out the used material, and refill with fresh absorbent.

22. Why can prolonged work be done without building up resistance to breathing in the absorbent?

The chemical used for absorbing carbon dioxide does not change form and so does not block the air course.

23. How would you sterilize the apparatus?

By placing the facepiece, breathing tubes and breathing bag in a sterilizing solution, then wash well in clean water.

24. Describe the methods of counteracting the fogging of lenses.

By either giving the wiper blade one sweep across the lens, or by a liberal use of anti-fogging solution to the inside of the lens before putting on the facepiece.

25. Describe the circulation of oxygen through the Drager apparatus.

Please refer to page 86, sections "Closed Circuit Operation" and "Constant-flow Metering."

26. What are the main purposes of the tests of the breathing-apparatus?

The main purposes of the tests of the breathing-apparatus are to determine air-tightness and proper functioning of the working parts.

27. Why is it necessary to examine apparatus connections?

It is necessary to examine apparatus connections to see that all gaskets are in place and the connections airtight.

28. Why should a rescue team, after entering a poisonous atmosphere, stop soon after leaving fresh air for a short time?

A rescue team entering a contaminated atmosphere should stop near fresh air for a short time so that if a team member is not capable of proceeding on the trip the team can return to fresh air quickly without undue hazard. It also gives the team members an opportunity to adjust themselves to existing conditions and gives the captain time to recheck the team and the apparatus.

Other Types of Self-Contained Breathing-Apparatus

Other types of self-contained breathing apparatus have been found useful under certain conditions. The Chemox Oxygen-Breathing Apparatus, Demand types of breathing apparatus using compressed air and the Oxy SR 45 M are described below. Owing to the limited time they can be used, they are recommended to be used only as auxiliary equipment.

Compressed air if used in breathing apparatus, should be of high quality and purity, and contain at least 20.5 per cent of oxygen and not more than 0.005 per cent of carbon monoxide. Four types of U.S. Bureau of Mines Approved portable compressed air apparatus (½hour), using an open circuit and demand type regulator are available. These are the Scott Air Pak, the M.S.A. Air Mask, The Globe Guardsman and the Surviv-Air.

CHEMOX OXYGEN BREATHING-APPARATUS

The Chemox Oxygen-Breathing-apparatus (Fig. 40) is a self-contained, closed-circuit machine employing a replaceable canister containing a chemical which, when in contact with the moisture in the exhaled breath, evolves a supply of oxygen for breathing requirements and absorbs the exhaled carbon dioxide and moisture. This apparatus, has been approved for one hour, by the U.S. Bureau of Mines. It affords the wearer complete respiratory protection in atmospheres which are gaseous or deficient in oxygen.

Parts of the Apparatus

The apparatus has six main parts: the facepiece and breathing-tubes, the frame and harness, the manifold, the breathing-bag, the canister, and the time-limit warning bell.

Facepiece

The facepiece is full-vision with a speaking-diaphragm. It has corrugated-rubber inhalation and exhalation tubes, fastened respectively to the left- and right-hand sides of a metal housing which holds the inhalation, exhalation and pressure-relief valves and is connected to the lower part of the face piece. The breathing tubes are connected to the manifold by their respective couplings.

Frame and Harness

The frame consists of an aluminum breast-plate and canister-holder. These are covered on the outside with a padded, rubberized fabric to protect the wearer from the heat of the canister when in use. The frame is carried by webbing shoulder- and waist-straps. The canister is supported by a swinging bail, or stirrup, attached to the metal holder and is tightened into place against the manifold by means of a jack-screw and hand-wheel on the bail. A rubber gasket forms the seal between the canister and the manifold.

Manifold

The manifold is a metal distribution chamber or box attached to the top of the framework over the canister-holder. A metal tube passes down through the centre of the manifold chamber and a cone-shaped socket-casting at the bottom of the manifold into which the neck of the canister fits. The lower end of the tube has a puncturing nose for breaking the copper-foil seal of the canister and fits into a tube in the centre of the canister. The upper end of the tube has a coupling for attaching it to the exhalation tube. Outside the tube in the base of the manifold there is an annular opening leading to the chamber of the manifold. This opening connects with the outer circuit of the canister. On the side of the manifold there is a connection leading from this chamber to the right-hand

Fig. 40—Man wearing Chemox Oxygen-Breathing-apparatus

section of the breathing-bag. A bracket on the side of the manifold carries an elbow which connects the left-hand section of the breathing-bag and the inhalation tube.

Breathing-bag

The breathing-bag is made of rubberized fabric. It is divided into two sections, one on each side of the canister-holder, connected together at the top. The bag is held in position to the frame by the connections with the manifold at the top and by a bolt to the frame at the lower end of each section.

Quick-Start Canister (Fig. 41)

The quick-start canister is a metal container filled with an oxygen-producing chemical (potassium superoxide). It is held in the holder between two sections of the breathing bag, and weighs four pounds before use.

An oxygen candle, fired by pulling on a cord lanyard, is attached to the bottom of the canister.

Warning Bell

The apparatus is fitted with a warning bell which is pre-set and warns the wearer when it is time to leave the working place. It is attached to the upper part of the manifold.

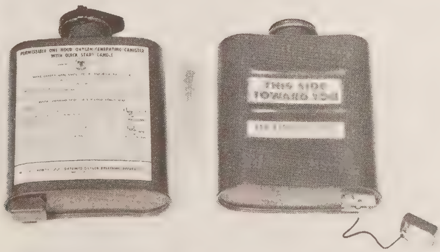


Fig. 41—Quick-Start Canister.

Oxygen Flow Through Apparatus

The flow of oxygen in the apparatus is shown in Fig. 42. During exhalation the flow is from the facepiece through the right-hand breathing-tube, the metal tube through the manifold chamber and the seal-puncturing nose, and down the centre tube of the canister to the bottom. The oxygen then flows up through the chemical, which absorbs the carbon dioxide and the moisture and liberates oxygen, to the top of the canister. From here the flow continues to the bottom of the right-hand side of the breathing-bag, then to the bottom of the left-hand side of the breathing-bag, from which it flows into the facepiece through the left-hand breathing-tube.

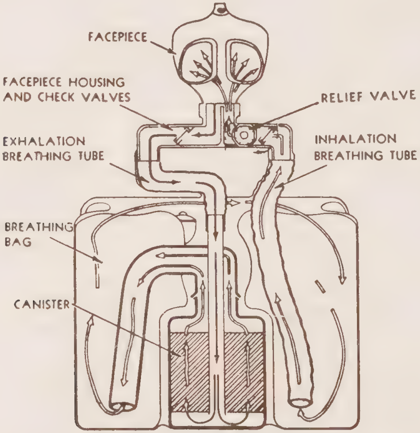


Fig. 42—Oxygen Flow through Chemox Apparatus

INSTALLING QUICK STARTING TYPE CANISTER

A. Lift up on lip of plastic cap until seal is broken. Completely remove the remainder of the cap, exposing the air

tight copper foil canister seal. This Copper Foil Seal Must Be Fully Exposed Before Inserting Canister.

B. With the handwheel screwed down far enough for the bail to be swung outward, swing the bail outward and insert canister fully into canister holder with the smooth side to the front. The canister should be inserted sufficiently so that the copper foil seal is punctured and the rubber gasket fits snugly against the V-shaped recess in the plunger casting. Screw the handwheel clockwise until it is tight against the canister.

C. Remove candle cover by rotating swivel plate 180°. Pull swivel plate down, push cover toward center of canister and let cover dangle. WARNING: DO NOT PULL LANYARD UNTIL READY FOR USE:

NOTE: The Canister Must be Inserted With The Smooth Side To The Front.

DONNING OF APPARATUS

The following are the consecutive steps in putting on the apparatus before entering a toxic atmosphere. *The Apparatus Must Always Be Put On In Fresh Air.*

1. Unfasten and straighten all harness straps.

2. With one hand, grasp the apparatus by the plunger casting, dropping the facepiece over the hand holding the apparatus. With the other hand grasp the D-ring assembly where the two large web straps join, placing the breast plate of the canister holder on the chest and slipping the head through the V-shaped opening formed by the two web straps.

3. Continue to hold the apparatus on the chest with one hand and with the other reach around the body at one side and grasp the free end of the web strap on that side. Bring the end of the strap under the arm and snap into the D-ring located on the top side of the breast plate. Repeat this procedure for the other strap.

4. Adjust the position of the apparatus on the body by means of metal slides located on the web harness straps. The position of the apparatus on the body should be such that when the facepiece is put on, the breathing tubes will permit free head movement.

5. Attach the waist strap to the small D-ring located on the lower corner of the breast plate and pull up to a snug fit, tucking in the loose ends.

6. Pull out the facepiece headband straps so that the ends are at the buckles and grip facepiece between thumb and fingers. Insert chin well into the lower part of the facepiece and pull the headbands back over the head. To obtain a firm and comfortable fit against the facepiece at all points, adjust headbands as follows:

(a) See that straps lie flat against head.

(b) Tighten lower or "**Neck**" straps.

(c) Tighten the "**Side**" straps. (Do not touch forehead or "**Front**" strap.)

(d) Place both hands on headband pad and push in toward the neck.

(e) Repeat operations (b) and (c).

(f) Tighten forehead or "**Front**" straps a few notches if necessary.

Test the facepiece for tightness by squeezing the corrugated breathing tubes tightly. Inhale gently so that the facepiece collapses slightly and hold breath for ten seconds. The facepiece will remain collapsed while the breath is held providing the assembly is gas tight. If any leakage is detected around the facial seal, readjust head harness straps. If other than facial seal leakage is detected, investigate the condition and correct. The facepiece must be subjected to a tightness test before each use.

7. With the facepiece adjusted and checked for tightness, start the Canister by the following method.

STARTING QUICK STARTING TYPE CANISTER
This Must Be Done In Fresh Air.

(a) Pull lanyard straight out away from body. Removal of cotter pin fires candle, inflating breathing bag with oxygen within 15 seconds.

NOTE: If Candle Fails To Fire, Insert New Canister.

(b) Starting of the candle may be accompanied by a slight amount of harmless smoke. The breathing bag will be inflated with oxygen.

After intial start and use of canister, do not attempt to restart and reuse either type of canister.

The CHEMOX Apparatus Should Be Stored And Started At Temperatures Above 32° F. When a Quick Start Canister is used, the apparatus can be started at temperatures as low as -20° F.

8. To check the complete apparatus for tightness.

(a) Grasp the lower end of the inhalation (left hand) breathing tube and squeeze it tightly. Inhale gently and if the facepiece collapses, the facepiece seal is sufficiently tight and the exhalation value is functioning properly. This will also test the upper part of the inhalation breathing tube for leaks.

(b) Continue to squeeze the lower end of the inhalation (left hand) breathing tube. Depress the pressure relief valve button, It should then be possible to exhale through the valve. While still holding the button down, inhale and if the facepiece collapses as above, the relief valve is functioning properly.

(c) Release the inhalation (left hand) tube and squeeze the lower end of the exhalation (right hand) breathing tube. Inhale and then exhale forcibly. The exhaled air should be forced out between the face and the facepiece only, this will indicate that the inhalation valve is functioning properly and the upper end of the exhalation tube is free of leaks.

(d) With the bag well inflated, grasp the upper ends of both breathing tubes and squeeze tightly, and depress both sides of the breathing bag with the elbows. If The Breathing Bag Does Not Deflate, The Complete Apparatus Is Tight.

If A Leak Or Defect Is Indicated In Any Part Of The Apparatus. It Should Be Checked And The Condition Corrected Before Use.

9. Breathe normally as the apparatus furnishes enough oxygen to meet any breathing requirement.

Use of the Timer

Since the apparatus has a nominal one hour service life as indicated below, it is necessary to determine the length of time required to return to fresh air from the working place and set the timer accordingly. The timer dial is calibrated in minutes, and by turning the pointer clockwise to the number of minutes left after deducting the time for exit, the timer will be properly set. For example, if it takes ten minutes to return to fresh air, deduct 10 minutes from 60 and set the timer at 50. The bell on the timer will ring for approximately seven seconds when the pointer returns to zero, at which time the wearer must return immediately to fresh air.

SERVICE LIFE

This equipment is approved by the U.S. Bureau of Mines as a "one-hour" unit. The duration of the unit will depend on factors such as:

(a) The degrees of physical activity of the user;

(b) The physical condition of the user;

(c) The degree of which the user's breathing is increased by excitement, fear, or other emotional factors;

(d) The degree of training or experience which the user has had with this or similar equipment;

(e) The condition of the apparatus.

GENERAL INFORMATION FOR USE

The canister will produce more oxygen than will be used so the breathing bags will become over inflated, causing exhalation resistance. The excess volume can be eliminated (vented) by depressing the valve button on the facepiece. Do not over vent.

There are two indications in addition to the timer that the canister is becoming expended—fogging of the lens(es) on inhalation and increased resistance of exhalation. These two indications will not normally appear until after one hour of use but may become noticeable under conditions of extreme hard work. The lens(es) will clear on inhalation until the canister is almost expended, then they will begin to fog. Do not confuse excess breathing bag pressure with canister resistance. If excess breathing bag pressure is relieved by use of the pressure relief valve and the exhalation resistance is still present, the canister is about expended.

If Either Of These Two Indications Appear, Return To Fresh Air.

CAUTION

Never Allow Any Substance To Enter The Neck Of The Canister, Especially Oil, Water And Oil, Gasoline, Grease, Etc., As The Chemical Contains Oxygen, Which Will Cause Combustion Of Any Inflammable Materials With Which It Is Brought Into Direct Contact, Especially If Such Materials Are Moist.

AFTER USE

1. To remove the canister turn the handwheel down, swing bail outward and remove the canister with the hand suitably protected by a glove or other covering since the canister may be hot. Do Not Reuse The Canister.

2. Always use the following procedure before discarding the canister: To dispose of canister, remove to surface,

punch a small hole in front, back and bottom, and place in bucket of clean water sufficiently deep to cover the canister at least three inches. When bubbling stops, any residual oxygen will be dissipated and the canister will be expended. Pour the residual water which is caustic, down a drain or dispose of in any other suitable manner and then discard the canister. Do Not Puncture Canister Underground.

CLEANING AND SANITIZING

The facepiece and breathing tube assembly (disconnected from the apparatus by detaching coupling nuts) should be cleaned and sanitized after each use.

1. Immerse soiled equipment in sanitizing solution and scrub gently with a soft brush until clean.
2. Rinse in plain warm water (about 120° F.) and then air dry.

None of the metal, plastic, rubber, leather, cloth, or glass parts will be adversely affected by the cleaning solution.

The inhalation and exhalation check valves are removable from the facepiece and breathing tube assembly by disconnecting the clamps, removing the breathing tubes and sliding the valves out. They should be checked periodically and cleaned or replaced if necessary. DO NOT remove the valve from its seal during cleaning. This will prevent improper reassembly. Dry valves throughly after cleaning. Replace each valve assembly in the side from which it was removed. Each valve assembly and housing is indexed with ridges and slots for correct replacement.

While the apparatus is not in use, there should be a periodic check of the plunger and plunger casting (the part which pierces the canister) for cleanliness and free movement of the plunger. The tightness of the apparatus should also be checked periodically using the procedure outlined in Donning of Apparatus.

When any part shows evidence of failure, it should be replaced immediately with a new part. Apparatus which becomes damaged should be returned to the factory for repair.

STORAGE

When not in use the apparatus should be kept in the carrying case provided and canisters should be stored in a dry place.

DEMAND APPARATUS

Scott Air Pak **M.S.A. Air Mask**

(see page 142)

The Scott Air-Pak may be used safely in any atmosphere containing any gas except one which irritates or poisons through the skin, such as hydrogen cyanide or highly concentrated ammonia. It may be used under conditions of heat, cold, pressure or mist in which a man can work.

Model No. 6000 A2M or the Scott Air Pak II are approved by the U.S. Bureau of Mines for a ½ hour of continuous use with a fully-charged air-cylinder having a capacity of 40.3 cubic feet at 1,980 psi. Its total weight is 29½ pounds.

The purity of the air used to recharge Air-Pak bottles is of prime importance as the compressed air must contain not less than 20.5 oxygen and not more than 0.0005 carbon monoxide. Many companies use the same equipment for compressing air as they use for filling oxygen cylinders thus assuring themselves of the purity of the air. This type of compressor uses water, or soap and water, lubrication and the cylinders of the compressor are usually water cooled to eliminate the formation of carbon monoxide which could be caused through the heat generated.

Air compressors using oil lubrication may be used as a source of compressed breathing air only when carbon monoxide indicating devices are used in the circuit continuously to check the purity of the air and the air is properly filtered.

Parts of the Apparatus

The Scott Air-Pak has five main parts: an alloy metal cylinder, or bottle, containing pure breathing air; a reducing valve and demand regulator with a shut-off valve and by-pass valve; a facepiece and corrugated breathing tube with "quick connect" coupling; a metal backplate to which is fastened the web-type carrying harness; an auxiliary charging hose and the female half of a high-pressure self sealing coupling.

Air-cylinder or Bottle

For purposes of clarity the term "bottle" will be used throughout this description. The bottle is made of a metal alloy and is much lighter than a steel bottle of comparative size would be. It is approved by the U.S. Interstate Commerce Commission and tested to a pressure of 3,000 psi. When charged to its present permitted pressure of 1,980 psi., it contains 40.3 cubic feet of air.

There is a main bottle-valve which should be opened at least one full turn when the Pak is being worn. There is a safety cap designed to fail under excess pressure.

The bottle is distinctively coloured and marked to identify its contents; it is painted a "canary yellow" and has, stencilled in black paint, the words "Pure Breathing Air Only" marked on the body of the bottle in large letters.

Fitted to the valve body is a pressure gauge known as the bottle-gauge which shows the bottle pressure at all times even when the main bottle-valve is shut off.

Attached to the bottle opening by means of a coupling nut is a "T" fitting, to this is attached a neoprene covered

high-pressure flexible hose about 18 inches long leading to the reducing valve and regulator; the other branch of the "T" has a pressure operated check valve to which is connected a neoprene covered high pressure flexible hose about 24 inches long ending in the female half of a high-pressure self sealing coupling. This latter hose is used when recharging the apparatus while wearing it, from one or more large cylinders.

Low-Pressure Alarm

An alarm bell is incorporated in the Scott II and is available for the 6000 A2M, to sound when the bottle pressure is reduced to approximately 400 psi. This bell cannot be shut off and and will continue to ring for 4 to 5 minutes, by which time the wearer will have emptied the bottle.

Fig. 43—Scott Air-Pak II in Carrying Case.

Reducing Valve and Regulator

The Scott Demand-type Regulator, delivers air to the user in accordance with his requirements. When the user inhales, the regulator delivers air from the bottle, reduced to a pressure approximately 3½ psi. above atmospheric pressure, during the inhalation period and in a volume dependent upon the depth of inhalation. This flow may reach a maximum of 340 litres per minute. When the user exhales, the regulator shuts off the air from the bottle, thus conserving the air supply.

The regulator assembly (Fig. 46) consists of (1) the regulator body and mechanism, (2) the high-pressure

Fig. 44—Scott Air-Pak showing general arrangement of harness, recharging hose, and two types of facepieces.

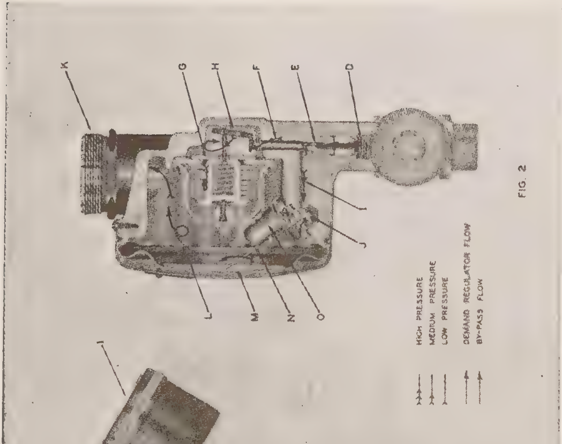


Fig. 45—Diagram of Air-flow through Scott Air-Pak Regulator

gauge, (3) the by-pass valve, (4) the regulator shut-off valve, (5) the shut-off regulator lock, and in the Scott Air Pak II, the low pressure alarm.

The high-pressure gauge is mounted on the regulator-housing in view of the wearer at all times. This gauge indicates the bottle pressure when the main bottle-valve is opened and provides a positive indication of the amount of air left in the bottle. The markings on the dial are luminous for maximum visibility.

The assembly is connected to the flexible hose from the bottle and fastened to the chest-strap of the harness. The regulator is connected to the breathing-tube from the facepiece by a "quick-connect" coupling. The regulator shut-off valve (yellow knob) is provided to shut off the air to the regulator if and when the by-pass valve (red knob) is in use.

A by-pass valve is provided for use in the event of damage to the demand regulator.

Operation of the Regulator (see Fig. 45)

Air at bottle pressure enters the regulator at A, passes through shut-off valve orifice B, and continues through passage C, through screen D, and orifice E. After being reduced by first-stage valve F to a lower pressure, the air continues past it to the inside of bellows assembly G, which is spring-loaded to maintain a constant pressure of 35 psi. in this chamber. If this pressure increases, the bellows expands, actuating lever H, which in turn closes first-stage valve F, reducing the presure. If the pressure in the bellows drops, the reverse takes places, building the pressure up to 35 psi., and maintaining the pressure in the bellows chamber at 35 psi. The air-flow pressure, now reduced to 35 psi., passes through passage I to demand valve J.

When the user inhales he creates a decrease of pressure or a suction in the mask and breathing tube assembly which is connected through "quick-connect" coupling K to chamber L. When the pressure in chamber L is reduced, the outside atmospheric pressure depresses diaphragm M inward, moving demand-valve stem N toward its open position. The demand valve then opens, permitting the air to flow from passage I and under the diaphragm. Since the area of diaphragm M is large and the spring rate of the demand valve is low, the negative pressure, or suction required for full opening of the demand valve is small. The variation in effort in breathing is not noticeable, regardless of whether the user is at rest or performing violent physical exertion.

Orifice E is protected by inlet screen D which has a total area of openings of over fifteen times that of the normal orifice opening. This provides adequate protection against any clogging of orifice E which would restrict the flow to less than maximum requirements.

If first-stage valve F sticks in the open position, permitting pressure in passage I to build up beyond 50 psi., safety valve O opens, discharging air in a continuous flow, at reduced pressure, directly into chamber L. Under such circumstances, the user would be warned that the initial reduction stage had failed. He would receive a continuous flow of air to the mask at an increased pressure. He should return to fresh air at once. It is almost impossible for valve F to stick in the closed position because the high pressure is applied to the underside of the valve. This would force the valve open under any conceivable condition.

Should demand valve J stick in the open position the flow of air through restricting orifice E would so limit the volume that there would only be a tendency to inflate the mask, and the pressure in the mask would be held

at less than three inches of water by the operation of the exhalation valve.

The Scott II Regulator, while differing in appearance, provides the same function in almost identical manner. It does however provide a greater air flow upon demand.

Facepiece and Breathing-tube

Two models of facepieces are available for the Scott Air-Pak. (See Fig. 44) Both are full-face, full-vision type. A rubber-diaphragm exhalation valve in front of the wearer's mouth permits talking or telephoning. Air is inhaled through a corrugated rubber tube connected to a Y-shaped fitting at the bottom of the facepiece. Each branch of the Y leads to the bottom of the lens. The inhaled air strikes the lens and clears off any fogging that may occur. The facepiece is held tight to the face by a six-strap headpiece.

The bottom end of the breathing-tube has a quick-connect female coupling which enables the user to connect or disconnect the breathing- tube easily and quickly, using his fingers only. When connecting, a sleeve approximately one inch long slides into the regulator orifice and the coupling nut is tightened. It is not necessary to use any tools to tighten the nut and the sleeve prevents the threads being cross-threaded.

Harness

The harness is made of a specially-treated webbing. The metallic snaps and buckles are treated to reduce sparking.

The harness consists of a back-plate under the bottle, two shoulder-straps, a chest-strap, and a waist-strap. At the top of the back-plate is a "D" ring for attaching a life-line.

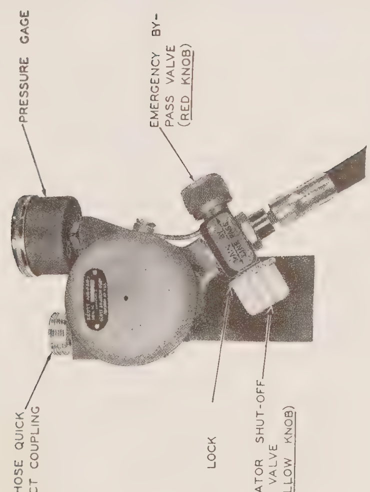


Fig. 46—(a) Scott Air-Pak Regulators.

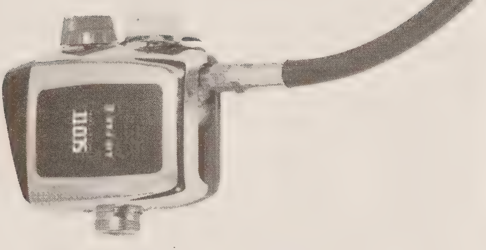


Fig. 46—(b) Scott II Regulator.

Charging Assembly

The superiority of this type of apparatus over other types of breathing devices is the ability to recharge the bottle when wearing the machine in an irrespirable atmosphere.

At the bottle opening a pressure operated check valve is connected to the tee fitting; this valve prevents air escaping from the bottle when the charging hose assembly is not in use. Connected to this check valve is a neoprene covered high-pressure hose about 24 inches long, the free end having the female half of a high pressure self sealing coupling (the male portion of this coupling has the self-sealing valve in it). This apparatus charging hose assembly is fastened when not in use, to the chest strap, on the right hand side by means of a snap buckle or small strap.

Directions for Operating the Scott Air-Pak

(see Fig. 46)

During normal operation of the apparatus the shut-off valve (yellow knob) should be fully opened and locked in position. It is provided to shut off the operation of the demand regulator in the event of damage or failure and should be closed only after the by-pass valve has been opened. The emergency by-pass valve (red knob) should be fully closed. It is provided for use in case the automatic demand regulator becomes inoperative. When opened it provides a continuous flow of air to the facepiece, by-passing the regulator mechanism. If required, the by-pass valve should be opened first, by turning counter-clockwise, then the regulator shut-off valve should be closed and the flow of air through the by-pass valve adjusted to suit the user's requirements.

WHEN OPERATING THE VALVES, TURN FIRMLY WITH THE FINGERS. DO NOT USE FORCE.

Fig. 47—Front view of man wearing Scott Air-Pak II

Tests for the Scott Air-Pak

Similar to all other breathing devices the Scott Air-Pak should be frequently tested between periods of actual use (at least once a month) to determine its condition, and should always be carefully tested for air-tightness and proper working order before it is worn. Any leaks and/or defective parts found during these tests should be adjusted, repaired or replaced. There is absolutely no excuse for wearing a breathing device that is known to be not working properly or is leaking.

When soapsuds have been used for detection of leaks at connections, the parts should be thoroughly cleansed after the test has been completed.

Repairs, adjustments or replacement of parts should only be done by the Station Superintendent or under his supervision, with the exception of the demand regulator. Any repairs or adjustments necessary to the regulator must only be done by the manufacturer, his agent or by a person authorized to make such repairs by the Director, Mines Engineering Branch.

STATION TESTS

Check the equipment to see if it is complete, paying particular attention to the harness, that no undue weakening has taken place through wear or chafing especially where the webbing passes through the back-plate and where the regulator loop fastens over the chest-strap.

Testing Bottle

Test for moisture in bottle—After the bottle has been charged, hold it in a vertical position with the valves down. Open the main bottle valve and close it quickly. If water is blown from the valve, it shows that moisture has gathered in the bottle. Accumulations of moisture

Fig. 48—Back view of man wearing Scott Air-Pak

Fig. 49—Right Side view of man wearing Scott Air-Pak

sediment, rust, or scale should be removed by taking the valve out of the bottle and cleaning the bottle.

Test for tightness of bottle valve—To test the main bottle-valve, firmly attach a metal cap, with the gasket provided for this purpose, to the outlet end of the valve under test, making sure that the bottle is fully charged, and open the valve to its fullest extent. Immerse the valve and neck of the bottle in water. Escaping bubbles around the valve stem indicate a leak in the packing gland. Close the main bottle-valve, remove the metal cap and again immerse the outlet of the valve in water. Bubbles indicate that the valve is not closed tightly or that it has a defective seat. Any leaks or defective parts found during either test should be repaired or replaced before the bottle is used.

All air bottles, like oxygen bottles, must be re-tested every five years to comply with Ministry of Transport regulations.

Test for Regulator and Regulator Hose Assembly

With the equipment connected (except facepieces and breathing-tube), open the bottle-valve and observe the bottle-gauge pressure. Observe the pressure of the gauge mounted on the regulator housing. The two gauges should check. Close the main bottle-valve. The regulator and regulator hose assembly should hold the trapped pressure. Should a drop in the pressure be shown by the needle of the regulator-gauge moving back toward zero, a leak is indicated.

Regulator Shut-off Valve—Yellow Knob

With the regulator shut-off valve and by-pass valve closed and the main bottle-valve open, draw air in from the "quick-connect" orifice by inhaling until the regulator-gauge is at zero. Then watch the gauge to see if the

pressure builds up. If the pressure rises, the regulator-shut-off valve is leaking.

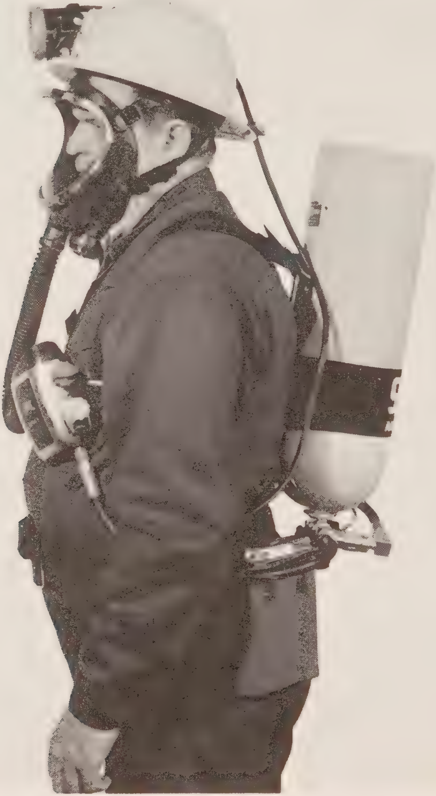


Fig. 50—Left Side view of man wearing Scott Air-Pak II

By-pass Valve—Red Knob

With the regulator shut-off valve and by-pass valve closed and the main bottle-valve open, place a soap-bubble across the "quick-connect" fitting on the regulator. If the by-pass valve is leaking, the bubble will expand and break.

Charging Hose Assembly

With the main bottle-valve in the full opened position remove the safety cap from the end of the charging coupling, immerse the end of the coupling in water. Any bubbles will indicate a leak in the pressure operated self-sealing valve. Check the connection by means of a soap and water solution. A leak in the hose may be found by immersing the hose in water when bubbles will indicate a leak.

Facepiece Test

Put on the facepiece and tighten the straps on the head-harness; seal the bottom of the breathing-tube with the hand, inhale, and hold the breath as long as possible. Do this several times. If the facepiece or the breathing-tube appears to leak, check the fitting on the face and, if the leak is still indicated, locate it or replace the face-piece and the breathing-tube with one you know to be in good order.

General Test

Connect the facepiece and plug in the "quick-connect" coupling and tighten the nut with the fingers and thumb; check the regulator performance. Inhale deeply and quickly. The regulator should supply a full flow to give the user, on demand, all the air he requires.

If, during slow light inhalation a "honking" or "chattering" sound is heard in the regulator, it can usually be stopped by breathing faster. If the bellows vibrate under

any breathing condition, the regulator should be changed and sent to the manufacturer for overhauling.

If the demand-valve sticks in the open position, air will continue to flow when the user is not inhaling. This condition can usually be corrected by blowing back into the regulator "quick-connect" opening. Check and recheck the regulator several times before discarding it.

FIELD TESTS

The Field Tests are to be carried out by the user each time the apparatus is worn, before leaving the fresh air base. Check the general condition of the apparatus paying particular attention to the harness.

High Pressure Test:

1. Open the main bottle valve and check the bottle gauge and the regulator gauge. The pressure registered on these gauges should correspond.
2. Close the main bottle valve. Watch the needle of the regulator pressure gauge; should the needle move steadily towards zero, a leak is indicated, and should be corrected. (Note—a drop in pressure here of less than 100 lbs. in 1 minute may be ignored.)
3. Release the trapped pressure through the by-pass valve to ascertain that the low-pressure alarm bell rings at about 400 p.s.i.
4. Re-open the bottle valve, put on and adjust the apparatus.

Facepiece Test:

Before connecting the breathing tube to the demand regulator, put on the facepiece, and adjust it. Place the hand on the bottom of the breathing tube and try to inhale. If the user can inhale, the facepiece may not be adjusted properly. Re-check the adjustment and try again. If a leak

is still indicated, locate and correct it, or replace the facepiece and breathing tube.

Regulator Test:

With the facepiece still on the face, connect the breathing tube to the regulator. Inhale and exhale several times to check the operation of the regulator.

Remove the facepiece until you are ready to enter the irrespirable atmosphere.

SCOTT AIR-PAK WITH EXTENSION HOSE

The equipment consists of a standard Scott Air-Pak equipped with an auxiliary connection in the air-supply line between the apparatus bottle and the regulator, and cylinders of compressed air equipped with a special supply hose. (See Fig. 53).

A person may travel in an irrespirable atmosphere, using air from the apparatus bottle he is carrying, to a place where there is an auxiliary supply of compressed air. Here he may recharge his apparatus bottle from a large cylinder by equalization, or obtain air directly from the large cylinder. A 244-cubic-foot cylinder, at 2,200 psi., will supply the user under normal conditions for a minimum of 6 hours. A "jumbo" size cylinder, with a capacity of 300 cubic feet at 2,400 psi., will supply the user for a minimum of 8 hours.

The complete Scott Air Pak with extension-hose assembly, consists of one or more large cylinders of air at the desired location with suitable manifolds if necessary; a "T" connection equipped with a pressure gauge; a high-pressure extension hose of the desired length equipped with the male half of a pressure-operated quick-connect coupling.

USES

The wearer may leave the fresh air base wearing this apparatus and, on arrival at the work site, while still breathing from the apparatus, may re-charge his bottle by connecting the free end of the coupling of his apparatus

Fig 51—Checking bottle and regulator gauges for pressure readings

to the coupling on the hose of the re-charge assembly. The following steps must then be done in order. (1) Open the valve on the large cylinder to re-charge his apparatus bottle by equalization. (2) Close the valve on his apparatus bottle. (3) Leave the couplings connected and the valve of the large cylinder open. This will enable him to breathe directly from the large cylinder for an extended period, and still have a full bottle for retreating to surface.

Fig. 52—Testing Facepiece of Scott Air-Pak II

When the operator is ready to return to the fresh air base he should open the valve on the apparatus bottle, close the main valve on the large cylinder, disconnect the coupling of the extension hose, and proceed to fresh air.

Demand Apparatus Cascade Recharge System

The success of the Demand Type apparatus in mine rescue work depends on the ability of the wearer to recharge his bottle without removal even though he be in an irrespirable atmosphere. This is done by taking to the working place, or, some place ahead of the fresh air base and as near the working face as possible, several cylinders of air compressed to a pressure of 2,400 psi., each cylinder when fully charged having a capacity of 300 cubic feet of free air; a suitable manifold for connecting two, three or more cylinders together; a charging hose assembly consisting of a coupling for connecting to the cascade manifold; a high-pressure gauge; a suitable length of flexible high pressure hose and the male half of a pressure operated self-sealing coupling, the female half of this coupling being a part of the apparatus worn by the user.

Method of Cascading

As the usual number of cylinders used for recharging bottles will be three in number this will be used as an example and standard throughout these instructions.

The first rescue team to go into a working place will transport with them the large cylinders to set up a cascade station ahead of the fresh air base. The cylinders are connected together by means of high pressure couplings which consist of a "T" fitting, a pressure-operated check valve and either a metal tube or a high pressure flexible hose and a charging hose assembly.

The charging hose assembly consists of one self-sealing coupling whereby the team can recharge their

bottles one at a time or, a manifold having several charging hose assemblies connected to it so that as many men may recharge their bottles at the same time as there are connections.

The charging hose assembly is always to be connected to the extreme left hand cylinder and the cylinders opened in turn from the extreme right. The cascading will always be counter clockwise, so that the right hand cylinder will always have the lowest amount of air in it, the next cylinder having the second lowest reading and the one on the extreme left being full or nearly so.

When the team captain sees that the lowest reading of the teams' bottle pressures is double the amount required to reach the cascade station he will order the team as a whole to return for recharging.

The team will proceed to the cascade station. When they arrive at this station each man will, without waiting for further orders, unfasten his charging hose from the chest strap. When there is only one charging hose, the man with the lowest reading will step forward and connect his charging coupling to that on the cascade. The team captain will then open the right-hand cylinder valve and when the pressure in the gauge on the apparatus corresponds to the pressure shown on gauge of the charging assembly of the cascade he will close that cylinder valve and open the cylinder valve on the next cylinder. The process is repeated and when the gauges have again equalized, that cylinder valve is closed and the bottle topped off from the last cylinder.

When more than one charging assembly is connected to the cascade the procedure is the same except the team captain will check all of the gauges of the machines connected to the cascade system. This is repeated until all the team have recharged their bottles.

Great care must be exercised by the team captain and checked by the man wearing the apparatus that; (1) the recharging operation starts from the lowest cylinder, (2)

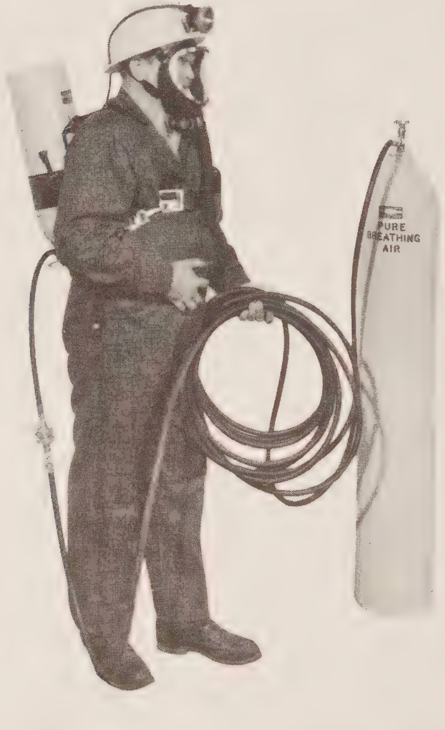


Fig. 53—Man Wearing Scott Air-Pak II with Large Cylinder and Flexible Extension Hose.

that the pressure shown on the gauges of the cascade system and the apparatus finally correspond; (3) that equalization is complete before closing the main cylinder valve and opening the next valve.

If after using the last cylinder in the cascade system the bottle is still not fully charged a full storage cylinder should be put into the cascade system. This is done by disconnecting the cylinder with the lowest pressure and removing it from the cascade system and putting the fully charged cylinder on the extreme left of the circuit.

It is the responsibility of the team captain to check the cascade immediately after being set up for correct sequence, functioning of check valves and tight connections.

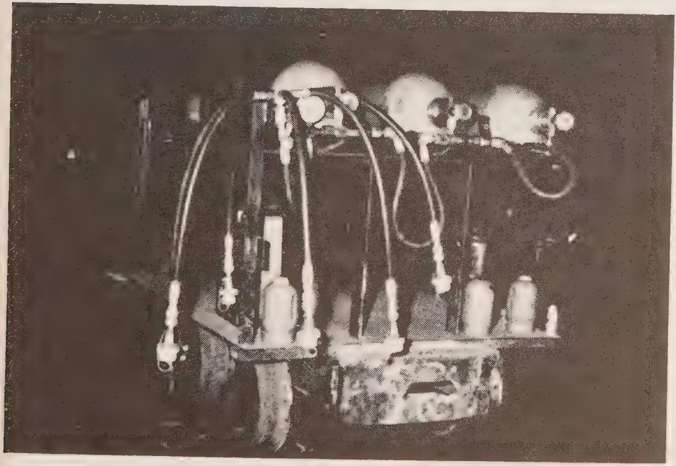


Fig. 54—A Three Cylinder Cascade System hooked up and with five self-sealing couplings on manifold.

M. S. A. AIR MASK

The M.S.A. Air Mask, (Fig. 55) is a self-contained breathing apparatus approved for use in toxic or oxygen-

Fig. 55—M.S.A. Air Mask.

deficient atmospheres. Its outward appearance may differ from the previously-described apparatus, but the procedures of testing and wearing, and its function are similar.

Fig. 56—Man Re-charging M.S.A. Air Mask with "Wear-N-Fill, Stand-N-Fill".

Parts of the Apparatus

There are five main parts: (1) a cylinder or bottle with a capacity of 45 cu. ft. of pure breathing air; (2) a demand regulator containing a shut-off valve, a by-pass valve and a pressure gauge; (3) a high-pressure hose with installed low-pressure "Audi-larm", connecting the demand regulator to the bottle.; (4) a facepiece assembly with built-in speaking diaphragm; (5) a light metal frame on which the bottle is mounted, a nylon harness resistant to water and chemicals, and "Cushionaire" shoulder straps.

In addition, a system called "Wear-N-Fill, Stand-N-Fill" is available, where-by the bottle of the apparatus may be recharged while being worn in contaminated atmosphere. The "Wear-N-Fill" portion is permanently connected to the apparatus and consists of a "T"-block, check-valve, high-pressure hose and the male half of a quick-connect coupling. The "Stand-N-Fill" portion is attached when in use, to the supply cylinder, and consists of the desired length of flexible high-pressure hose and the female half of a quick-connect coupling. (Fig. 56)

The application and method of use of the "Wear-N-Fill, Stand-N-Fill" is identical to that described earlier in this text. Both systems are ideal and are recommended for use by winze hoistmen or cage tenders during a mine fire.

DRAGER OXYGEN SELF-RESCUER—MODEL OXY-SR 45 M

The OXY-SR 45 M is a self-contained, closed circuit oxygen-breathing apparatus, which provides the wearer with breathing protection, entirely independent of the surrounding atmosphere for approximately forty-five minutes IF FULLY CHARGED TO 4410 p.s.i. If the cylinder is charged to only 3000 p.s.i. the time limit will be reduced to 20-30 minutes.

Fig. 57—Man Wearing Drager Oxy-SR-45 Self-Rescuer.

DESCRIPTION OF COMPONENTS

The plastic case contains an oxygen cylinder, a regenerative canister, a breathing bag, an oxygen control as-

sembly partially inserted into the bag, and a facepiece and corrugated breathing tube.

1. The oxygen cylinder when charged to a pressure of 4410 p.s.i. contains about 65 litres. The cylinder valve is operated by a turn-type lever and is equipped with a pressure-indicating gauge.

2. The regenerative canister filled with Soda Lime is fitted with upper and lower screens. The top screen is held in place by a tension spring under a retaining ring fitted over the top of a central tube which is inserted through the bottom of the apparatus. The cover of the canister contains two one-way valves to control the circulation of oxygen.

3. The breathing bag is made of tear-resistant rubberized fabric, with a capacity of 4.2 litres when fully inflated. The bag is fitted with reinforcing plates for the operation of the lung-controlled demand valve. The pressure relief valve is placed in the side of the bag so that if the bag becomes over inflated the valve opens in contact with the side of the case, permitting excess pressure to escape. A non-return check valve prevents the entrance of outside air.

4. An oxygen control assembly is held partly within the breathing bag by a tight fitting rubber collar over a double-flanged fitting. It consists of a miniature reducing valve, a constant flow metering device which delivers oxygen into the system at the rate of 1.2 litres per minute, and a lung-controlled demand valve. This assembly is attached to the oxygen cylinder by a finger-tight connection.

5. The facepiece is made of pliable rubber and is fitted with splinter-proof lens. The corrugated breathing tube is attached to a plastic cover that fits on top of the Soda-Lime canister.

PREPARATIONS FOR USE

Break the seal and open the case. Remove the facepiece which is folded in the cover. Unfold the breathing bag,

check the pressure on the gauge and open the cylinder valve. Press the reinforcing plate in the side of the bag against the demand valve until the breathing bag is nearly full. Remove the plug from the facepiece end of the breathing tube and adjust the facepiece on the face. Squeeze the breathing tube and try to inhale to test the seal around the face.

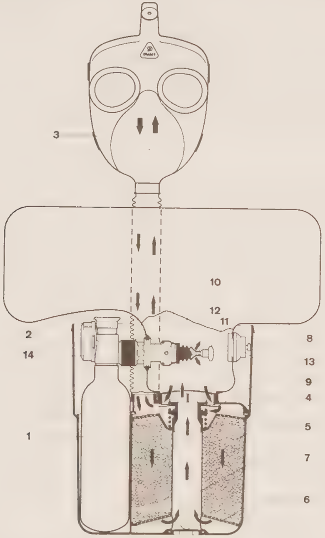


Fig. 58—Diagram Showing Circulation of Oxygen in Oxy-SR-45.

CIRCULATION OF OXYGEN

The exhaled breath flows down the single breathing tube, and through the Soda-Lime, where the carbon dioxide is removed. The purified air then passes up through

the central tube into the breathing bag where it is joined by oxygen being delivered from the constant flow metering device. On inhalation the air in the breathing bag passes through the one-way valves in the valve chamber and into the breathing tube. Should the flow of 1.2 litres per minute be insufficient for the wearer, the breathing bag will gradually deflate and the plate in the side of the bag will be pressed against the demand valve causing it to open, delivering an adequate supply of oxygen to the wearer. Should the bag become over-inflated the pressure relief valve will be pressed against the side of the case causing it to open and release the excess pressure to the outside atmosphere.

RECHARGING THE OXY-SR 45 M

Remove the oxygen cylinder and recharge. Loosen the screw coupling on the bottom of the case with the wrench provided, until the breathing bag and regenerator cover can be removed. Remove the oxygen control assembly from the bag. Detach the breathing tube from the cover by loosening the clamp. Remove the retaining ring by pressing it down and turning it until it is free. Lift the cover from the regenerative canister and empty the Soda-Lime. The central tube should be removed and the entire unit except the oxygen control assembly, washed and sterilized. After the parts are thoroughly dried, the apparatus may be reassembled, using approximately 1 lb. 2 oz. Soda-Lime to refill the regenerator.

STATION TESTS OF THE OXY-SR 45 M

1. Leak Test

Place a test cylinder in the apparatus and connect to the RZ 25 Tester using the connecting tube and facepiece adapter. Set the tester to Negative Pressure Pumping and empty the bag until the pointer rests between −80 and −100 mm. Set the tester to Leak Test and adjust the

pointer at 70 mm. H_2O by depressing the red button briefly. If the needle does not drop more than 15 mm. in one minute the apparatus may be considered satisfactory.

2. Dosage Test

With the apparatus still attached to the RZ 25 Tester, place a small plastic cap or a nut over the button of the relief valve to prevent it being opened during this test. Open the cylinder valve, set the testing unit at "Dosage" then press the side of the bag against the demand valve until the bag is almost fully inflated. Watch the pointer on the tester, it should read between 1.15 to 1.45 when using a cylinder charged to 3000 p.s.i.

3. Testing the Relief Valve

Remove the cap over the button of the relief valve, set the testing unit to Leak Test. Watch the positive pressure at which the needle stops. This is the pressure required to open the Relief Valve. It should open between +20 to +60 mm.

4. Testing the Demand Valve

Set the testing unit to Negative Pressure Pumping and slowly operate the pump until the demand valve is heard to open. This should occur between −10 and −40 mm.

A positive pressure leak test may also be carried out by using the cap over the relief valve and by inflating the bag with the pump of the testing unit.

Oxy SR 45 apparatus maintained at all Ontario Mine Rescue Stations are intended to be used for emergencies only. One or two units will be opened and used for training mine rescue teams in its use. The remainder will be retained in a sealed condition, ready for immediate use.

Station Tests described previously will be conducted on each Oxy SR 45 at twelve-month intervals by the Mine Rescue Station Superintendents. The cases will then be

re-sealed. No tests are required immediately before the apparatus is to be worn.

Two Oxy SR 45 apparatus, in sealed cases, will be carried as emergency equipment by each mine rescue team operating during a mine fire. Additional units may also be carried for the purpose of evacuating trapped miners through hazardous gaseous atmospheres.

Questions on Chapter V

1. What procedure should be followed to insure that the Demand-type apparatus will be ready for instant use?

A full bottle should be in the apparatus at all times and the main-line valve should always be left open to prevent the possibility of an attempt to use the appratus with the oxygen supply shut off.

2. What is the maximum allowable pressure for filling bottles?

These bottles can be filled to 1,980 psi., 135 atmospheres.

3. May compressed air from any source be used to refill air-bottles?

No. Only air that is certified to be pure should be used.

4. What tests should be made with apparatus before entering a toxic atmosphere?

(a) Open the bottle-valve, then close it and watch the regulator gauge to see if the pressure drops. If it does not drop more than 100 pounds in one minute, the apparatus is ready for use. Reduce pressure to check alarm.

(b) Block the breathing-tube shut and inhale. If the facepiece collapses against the face, the apparatus is air-tight. If air draws in around the edges of the facepiece, tighten the head-straps until no leakage can be detected.

5. What should be done if the air supply is cut off?

Open the emergency by-pass valve and return to fresh air immediately.

6. Name the six main parts of the Drager BG 174.

7. Describe the procedure when testing a Type "N" Mask before wearing it.

8. What use may be made of the Oxy-SR-45 Apparatus?

9. What is the time limit of the Oxy-SR-45 when the cylinder is charged to (a) approx. 4000 psi. and (b) approx. 3000 psi.?

CHAPTER VI

Auxiliary Equipment to Drager BG174 Apparatus

DRAGER UNIVERSAL TESTER, MODEL Rz25 (Fig. 59)

The Universal Tester is a multi-purpose unit for use in the testing of the Drager BG174 Oxygen Breathing Apparatus and other similar types of breathing equipment.

When used for testing the BG174, it will perform the following functions; (as explained in detail under "Field Tests" and "Station Tests", Chapter V)

1. Negative leak test
2. Operation of Automatic demand valve
3. Operation of constant-flow metering orifice
4. Positive leak test
5. Operation of relief valve
6. Operation of warning signal

Drager Rz35 Leak Tester (Fig. 60)

The Rz 35 Tester is a compact unit that may be used for the negative pressure testing of Drager BG 174 Breathing Apparatus as in Field Test No. 3. An aspirator bulb with rubber tubing attached is used to exhaust the air from the apparatus during the test. Mouth aspiration may be applied to the tubing as an alternative means of exhausting the air.

The Rz 35 Tester is a precision measuring instrument and should therefore be handled and used with normal care. Careful handling will assure a proper test and a minimum of maintenance.

HIGH PRESSURE OXYGEN BOOSTER PUMPS

NO OIL OR GREASE OF ANY KIND SHOULD BE USED IN ANY TYPE OF HIGH-PRESSURE OXYGEN PUMP. CHEMICAL ACTION BETWEEN THE OIL OR GREASE, AND THE OXYGEN IS POSSIBLE AND IS VERY LIKELY TO RESULT IN A VIOLENT EXPLOSION.

The following pumps are multi-valve piston type pumps for compressing oxygen and transferring it from one cylinder to another at a desired higher pressure. Pumps are available in either hand-operated or power-driven types.

(A) *Drager High Pressure Oxygen Pump*
(Fig. 61, 62, & 63)

This unit is a two-cylinder pump, capable of boosting the pressure in the cylinder being charged to either 2000 or 3000 p.s.i., according to the setting of the automatic control. THE 3000 p.s.i. SETTING MAY BE USED *ONLY* WHEN CHARGING DRAGER BG174 or OXY-SR BOTTLES

The level of the lubricant in the reservoir of the Drager pump must always be visible in the glass gauge tube on the end of the reservoir. During pumping operation, the circulating lubricant must be observed in motion beneath the two plastic domes on the console.

The lubricant mixture should be in the ratio of one part pure glycerine to four parts water.

Complete operating and maintenance details are described in the Drager Pump Manual.

(B) *M.S.A. High Pressure Oxygen Pump* (Fig. 64)

This unit is a single cylinder type pump, capable of boosting the pressure in the cylinder being charged to 2200 p.s.i.

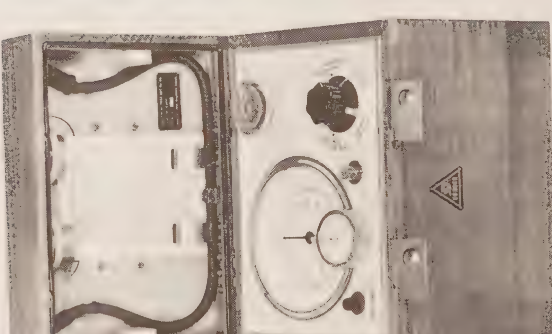


Fig. 59—Rz25 Tester

Fig. 60—Rz 35 Tester

Fig. 61—Drager Oxygen Pump with Bottle Connected

The M.S.A. pump should be kept fully lubricated with a mixture consisting of 40 per cent pure glycerine to 60 per cent water. By keeping the pump properly lubricated, and the leather gaskets, valves and piston rod in good condition, there will be a minimum of wear on pump parts, and changing the piston rod or re-packing the pump valves should seldom be necessary.

Complete operating and maintenance details are described in the M.S.A. Pump Manual.

Fig. 62—Drager Oxygen Pump, Control Panel

Charging Apparatus Bottles by Equalization

A system has been adopted whereby small apparatus bottles may be re-charged by equalizing their pressure with that of large cylinders. A manifold has been designed to be connected to two or three large cylinders as shown in Fig. 65 and 66. The large cylinders may be either horizontal, as in the cylinder compartment of the mine

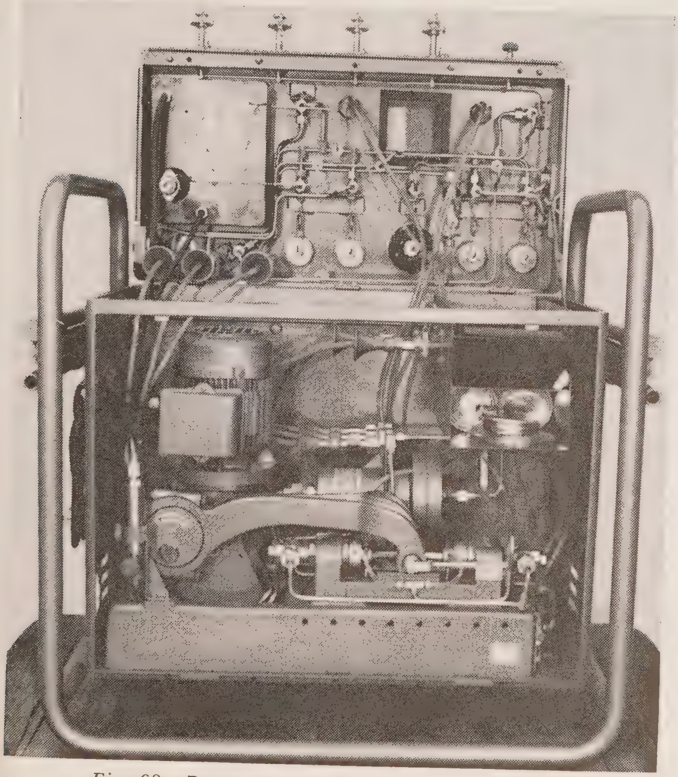


Fig. 63—Drager Oxygen Pump, covers removed

rescue truck, or upright. Upright cylinders should be chained or fastened to prevent their falling over.

Arrange the cylinders so that the one with the lowest pressure is to the right as you are facing them, and the

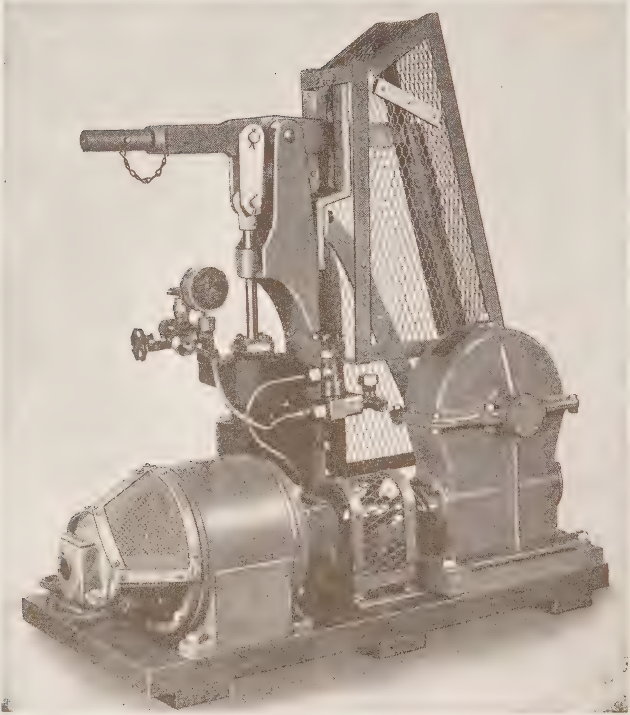


Fig. 64—M.S.A. High-pressure Oxygen Pump

one with the highest pressure is on the left. Connect the rigid inlet coupling of the manifold to the centre one of three cylinders, and attach flexible hoses to the outer cylinders. A special coupling containing a filter is used

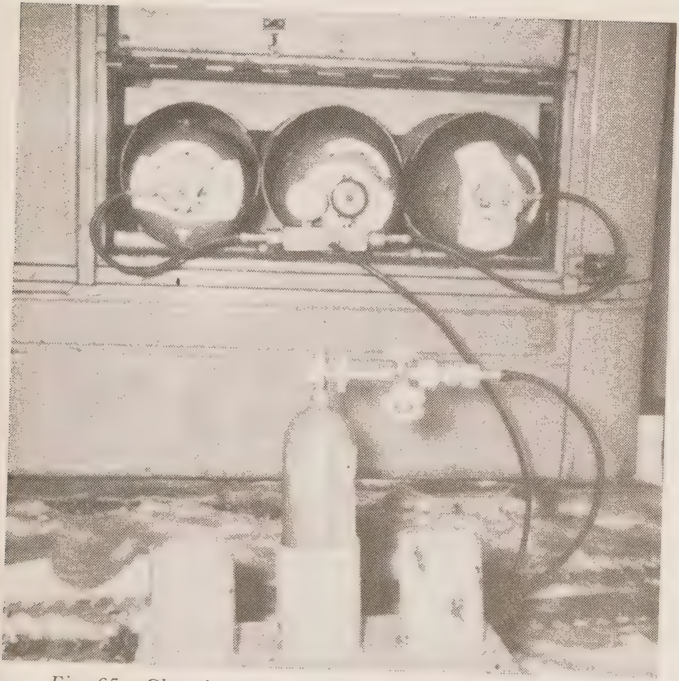


Fig. 65—Charging apparatus bottles with large cylinders in horizontal position, showing re-charging manifold.

to connect the small bottle being filled to the manifold. Care must be taken to see that the oxygen flows in the direction of the arrow on the filter.

To re-charge the small bottle, the following procedure must be adhered to:—(1) Open the main bottle valve on the small bottle. (2) Open the valve on the right hand cylinder, and close it again as soon as all sound of the

flow has stopped. (3) Repeat with the valve on the centre cylinder. (4) If necessary, repeat with the third cylinder. (5) Close the bottle valve, the main adaptor valve and the large cylinder valve. Open the bleeder valve on the adaptor and disconnect the bottle. All valves should be opened slowly to prevent excessive heat generation.

If only two large cylinders are available, remove the hose on the left side of the manifold, and close off the opening with the cap attached to the manifold. The same re-charging procedure should be followed.

Oxygen and Oxygen Containers

The purity of the oxygen used in rescue apparatus is very important, as impurities tend to accumulate in the circulatory system of the apparatus. The U.S. Bureau of Mines specifies that oxygen for use in rescue apparatus shall contain at least 98 per cent. of oxygen, no hydrogen, and not more than 2 per cent. of nitrogen, with traces of argon. Oxygen made by liquefaction processes conforms to this standard and contains no impurities other than nitrogen, with traces of the rare inert gases.

Small oxygen-cylinders or bottles as used in oxygen breathing-apparatus and oxygen inhalers range in capacity, when fully charged, from approximately 3 to 16 cubic feet. All cylinders used to transport oxygen and other non-liquified gases whose pressure exceeds 300 psi. at 70° F. must comply with the requirements of the U.S. Interstate Commerce Commission and the Ministry of Transport, Canada, as to strength, and all such cylinders which exceed 12 inches in length must have valves equipped with an approved safety device (bursting disc). They are therefore subjected to rigid tests by cylinder manufacturers, as prescribed by regulation.

All cylinders that have an outside diameter of 2 inches or more must be retested by hydrostatic pressure at least

once every five years and the date of retesting must be marked on the cylinder as required by the Ministry of Transport. Such retesting is made at a nominal charge by oxygen manufacturers.

The five-year tests consist of determining the "elastic expansion" (total expansion minus permanent expansion) when the bottle is subjected to a hydrostatic pressure of

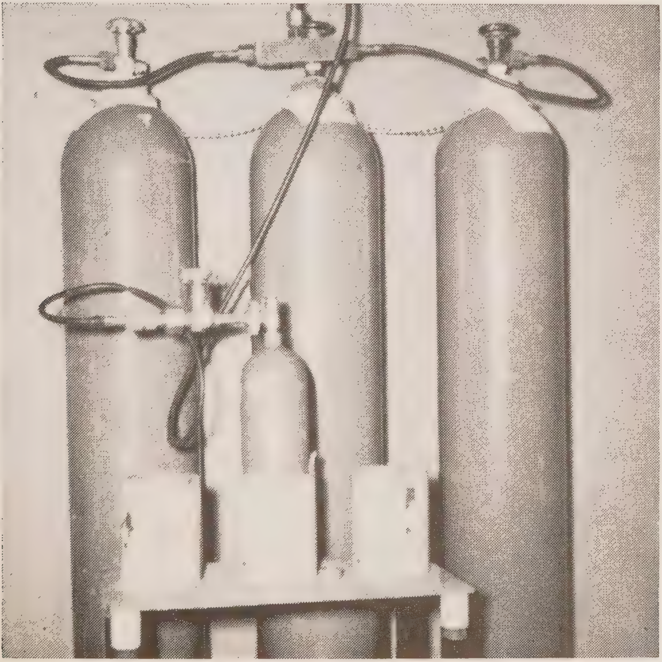


Fig. 66—Charging apparatus bottles with large cylinders in vertical position.

4,000 psi. It will be noted that the oxygen-bottles, which are usually charged at about 135 atmospheres, are tested at 4,000 p.s.i. Those capable of being charged to 3000 p.s.i. are tested to 4400 p.s.i.

Air or Oxygen Bottle Deterioration

When drawn from the large cylinder the air or oxygen contains some moisture, which is carried into the small bottle during refilling. The moisture hastens oxidation of the steel of the bottle, causing scale, sediment, rust, and pitting, and weakens the walls of the bottle. These changes occur with no visible sign on the outside of the bottle. Visual examination of the inside often fails to disclose defects. Hydrostatic pressure is the only means by which the condition of the bottle can be determined.

Questions on Chapter VI

1. Describe the method of charging bottles by equalizaion.
2. What lubricant mixture is used on the oxygen pump?
3. Why is it dangerous to use oil or grease for lubricating the pump?
4. Describe the method of making the "Negative Leak Test" on the BG 174 with the Rz 25 Tester.
5. When and when only may the 3000 p.s.i. setting be used on the Drager High-Pressure Pump?
6. Why should oxygen cylinder valves be opened slowly?
7. What standard of purity is required for oxygen used in oxygen-breathing apparatus?
8. How often, and at what pressure are Drager BG 174 cylinders tested?

CHAPTER VII

General Rescue Team Emergency Practices

Maintenance of Rescue Teams on Rescue and Recovery Operations

All members of mine rescue teams should report ready for work fully equipped with suitable clothes.

All members of rescue teams sent underground should have had adequate training in such work.

In order that members of rescue teams may keep physically fit during mine rescue and recovery operations, the following arrangements should be made and adhered to.

(a) No member should remain longer than 6 hours on one shift. During this period no man should be permitted to remain under oxygen longer than 2 hours, unless it becomes necessary to search for an overdue team, or excessive travelling time is involved.

(b) No one should be permitted to undertake a second shift until after he has had at least 4 hours' rest.

(c) No one should be permitted to take a second shift in irrespirable air without having been examined and found physically fit by a physician or, in the absence of a physician, by the most competent person present.

(d) Bathing facilities, preferably shower baths with hot and cold water, should be available for the men coming off a rescue and recovery shift.

(e) Plain, well-prepared food, not too rich in sugar and fats, should be eaten in moderation. No food should

be eaten for one hour before taking active part in rescue and recovery work. This includes candy.

(f) Comfortable, clean sleeping quarters should be provided, where necessary, for members of rescue teams.

Objects of Rescue and Recovery Work and Exploration During and After Mine Fires

Careful consideration should be given to the method and extent of the exploration plan and whether the results that may be obtained justify it. Can it be made with safety to the rescue teams, and will it increase the possibilities of saving the lives of trapped men?

The three main objects of mine rescue and recovery work are locating trapped men and bringing them to surface, locating and extinguishing incipient or active fires and, after the fire danger is over, examination of the mine for assurance that there are no dangerous concentrations of noxious gas which would prevent normal operations in any portion of the mine.

The director of rescue teams should consider the following items when making his plans: probable conditions in the part of the mine to be explored as known from information already available; route of travel, visibility and familiarity with location; the number of rescue men available and the limitations of both men and apparatus.

Live men may be found behind barricades. The rescue of these men constitutes a local problem. Dead bodies may be found, but men encumbered by rescue apparatus should not ordinarily waste their strength in carrying such bodies any great distance to a fresh air base.

Rescue teams may be able to fight mine fires at close range and direct streams of water to the best advantage. When a mine fire cannot be fought directly on account

ROTATION OF MINE RESCUE TEAMS IN EVENT OF A FIRE UNDERGROUND

SIX-TEAM ARRANGEMENT

24-hour period

Date.......................................

Team No. and Description					*Two*	*Hour*	*Intervals*					
A.	Undg. & Report				Reserve	Stand-by at F.A.B.	Undg. & Report				Reserve	Stand-by at F.A.B.
B.	Stand-by at F.A.B.	Undg. & Report				Reserve	Stand-by at F.A.B.	Undg. & Report				Reserve
C.	Reserve	Stand-by at F.A.B.	Undg. & Report				Reserve	Stand-by at F.A.B.	Undg. & Report			
D.		Reserve	Stand-by at F.A.B.	Undg. & Report				Reserve	Stand-by at F.A.B.	Undg. & Report		
E.			Reserve	Stand-by at F.A.B.	Undg. & Report				Reserve	Stand-by at F.A.B.	Undg. & Report	
F.				Reserve	Stand-by at F.A.B.	Undg. & Report				Reserve	Stand-by at F.A.B.	Undg. & Report

The above arrangement is made up for a maximum force of 6 teams, and allows for six hours on duty and six hours complete rest. As more teams become available, and if the emergency indicates an extensive operation, a nine-team arrangement is advisable, whereby the team members would have a twelve-hour rest period.

Signed...

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of its magnitude or dangerous conditions, they can put in seals or bulkheads. When a sealed area is opened, teams with suitable apparatus may explore it and find whether or not the fire is out before ventilation is restored.

Number of Men Required for Standard Mine Rescue and Recovery Teams (see Figs. 67-68)

Oxygen breathing-apparatus should be used only when there are enough trained men available to perform the assigned work. Five men normally constitute a standard team for work in irrespirable atmospheres, but in extreme emergency, where life is involved, and conditions are carefully weighed, a minimum of three men may compose a team.

A team should not ordinarly be sent ahead of an established fresh air base unless there is a fully equipped team in reserve at this base.

Fifteen trained men is a satisfactory number to have on hand at a fresh air base to constitute and support a 5-man team working ahead of a fresh air base. Five men, in apparatus but not under oxygen, should remain at the fresh air base as a standby team. The remaining 5 men may be used as assistants at the fresh air base or as additional apparatus men if needed.

Time Limits for Rescue Trips

All watches should be synchronized and any instructions regarding time limits strictly adhered to. For returning to the fresh air base a team should ordinarily allow twice the amount of time used on the in-going trip.

If the amount of oxygen in the apparatus bottle worn by any member of a team has been reduced to twice the amount used on the in-going trip, the whole team should return immediately to the fresh air base.

An exception to this procedure may be made in cases where extensive exploration or gas testing has been done on the way to your objective. The time, or oxygen spent on these side trips need not be considered in estimating the amount needed for a direct return trip to fresh air.

If a rescue team is overdue in returning to the fresh air base, the standby team should be sent to look for it even at the cost of delaying operations.

Fresh Air Base

The fresh air base is the headquarters set up as a base of operations from which rescue and recovery work in irrespirable atmospheres may be conducted. A director of operations, with the required assistants, should be stationed at the base. If there are more than one of these bases it may be necessary to set up a general headquarters. The base may be on surface or underground, as conditions require, and should be as near the scene of operations as possible. The essentials of a fresh air base include the following: an assured supply of fresh air; an assured travelway for men and materials to surface in fresh air, if underground; communication with headquarters on surface by telephone or messenger; the best illumination possible; sufficient room to permit efficient work without confusion.

The fresh air base should be equipped with tables, benches for the reserve teams, benches for overhauling rescue apparatus, tools and repair parts for maintaining apparatus and the necessary tools and supplies for carrying on the work in hand.

There should be a sufficient staff to direct the work and maintain operations on the fresh-air side of the base.

Briefing a Team

Briefing a team should be carried out only after all decisions in connection with the operations to be con-

ROTATION OF MINE RESCUE TEAMS IN EVENT OF A FIRE UNDERGROUND

NINE-TEAM ARRANGEMENT

24-hour period

Date...

Team No. and Description					*Two*	*Hour*	*Intervals*					
A.	Undg. & Report							Reserve	Stand-by at F.A.B.	Undg. & Report		
B.	Stand-by at F.A.B.	Undg. & Report							Reserve	Stand-by at F.A.B.	Undg. & Report	
C.	Reserve	Stand-by at F.A.B.	Undg. & Report							Reserve	Stand-by at F.A.B.	Undg. & Report
D.		Reserve	Stand-by at F.A.B.	Undg. & Report							Reserve	Stand-by at F.A.B.
E.			Reserve	Stand-by at F.A.B.	Undg. & Report							
F.				Reserve	Stand-by at F.A.B.	Undg. & Report						
G.					Reserve	Stand-by at F.A.B.	Undg. & Report					
H.						Reserve	Stand-by at F.A.B.	Undg. & Report				
I.							Reserve	Stand-by at F.A.B.	Undg. & Report			

Signed...

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ducted have been made so that there will be no argument as to the proper steps to be taken once briefing commences. If possible, briefing should be done in a quiet room where questions may be answered and the work to be done by the team thoroughly explained, without confusion.

All pertinent instructions should be issued in writing to the team captain.

The time limits of the trip should be understood and watches synchronized.

Duties of the Captain of a Rescue Team

The team captain should take charge of and be responsible for the discipline, general safety and work performed by his team. HE SHOULD TAKE ORDERS ONLY FROM THE MINE OFFICIAL IN CHARGE OF THE OPERATION.

Preparatory to Going Underground

Preparatory to going underground the team captain should carry out the following procedure pertaining to the operation.

1. Ascertain that the members of the team are in fit condition to undertake the job.

2. Make sure that each member of the team inspects and completes the Field Tests on the apparatus he is about to wear. If Type N masks are being worn, new canisters should be used.

3. Check (or have members of the team check) the Flame Safety Lamp, CO Detector, signal whistles, telephone lines and telephones, link lines and if required, a guide line. Be sure that each team is equipped with two sealed OXY-SR 45 Apparatus. (during emergencies)

4. Understand the instruction clearly and discuss them with the team so that each man will understand what he has to do.

5. Note the time that the team has been given for the trip and synchronize watches with that of the official in charge.

6. See that the required tools and materials are on hand and equally distributed among the team so that each man will carry his share.

7. Make sure that he has a notebook, pencil and chalk to take underground with him.

8. Have the team put on the apparatus and "get under oxygen" when ready to proceed; then inspect their equipment.

(a) Headstraps and buckles. Lift hat for better view.

(b) Facepiece—straight, no kinks in tubes.

(c) Gauge reading—write it down.

(d) Overall condition of man.

(e) Vice Captain to make similar check of Captain's apparatus.

(f) Check signal whistles.

(g) Report to official in charge and note time of departure.

After Going Underground

After going underground the team captain should carry out the following procedure:—

1. Discourage excessive talking.

2. Note and write down any unusual conditions encountered during the trip. Make notes of all CO detector readings and safety-lamp observations. Mark all obstructions and unusual conditions on the map. Bear in mind the fact that the team will have to overcome the same obstructions and unusual conditions on the return trip.

3. Mark the course of travel, in chalk, by an arrow pointing to the fresh air base.

4. Shortly after entering contaminated air from fresh air, halt the team and re-check the condition of the team members, the gauge readings and the apparatus.

5. Proceed carefully and stop to rest as often as conditions warrant. During halts check gauges (visually) and apparatus. If the rescue of men is involved speed may be necessary but should be governed by conditions and common sense.

6. When passing through ventilating doors, leave them as found, unless specific instructions have been given to leave the doors open or closed.

7. A lighted flame safety lamp and a carbon monoxide detector should be part of the standard equipment carried by every mine rescue team travelling underground either in practice or in actual operations. Before a team captain permits any team member to remove his breathing apparatus while underground, he must be certain the air is safe to breathe. One indication of this may be the presence of other workmen without breathing apparatus, in obviously good condition.

If no such indication is present, tests for oxygen and carbon monoxide must be made, by observing the lighted flame lamp and by using either the Colorimetric or Drager detectors to check for carbon monoxide. The Colorimetric and Drager detectors must be given 1 squeeze with no change in color in the detector tube in either case.

8. Remember the fact that it will be just as necessary to halt and rest and check apparatus when retreating as when advancing. Keep the team from becoming upset by excitement if anything should happen to a member or if an apparatus should fail to function properly. Use the by-pass if necessary and return to the fresh air base as quickly as possible.

The success or failure of mine rescue and recovery operations depends a great deal on the ability of the team captains to lead their teams.

9. If any situation discovered underground requires action on surface, advance warning by telephone should be given wherever possible.

10. Carry out the orders given by the briefing official. Bring the team back to the fresh air base on time, even if the work assigned has not been completed. Make a report.

Rescue Team Organization

Rescue Team Guides

In a major fire it will generally be necessary to bring in rescue teams who are not familiar with the mine workings. To facilitate the necessary work in combatting the fire, a guide who has an intimate knowledge of the area is advisable. Trained supervisors are recommended.

Order of Travel

In mine rescue, as in any other team work, discipline is essential to efficiency. This discipline must be maintained both in training and in actual operations.

Teams should travel (except in special cases) in single file and approximately 4 feet apart. The team captain, or No. 1 man will always lead the team whether advancing or retreating, followed by numbers 2, 3, 4 and 5 in that order. Number 5 man assumes the responsibilities of vice-captain. If a trained supervisor accompanies a team, he should take the position as No. 2 man, where he would be in easy communicating distance to the Captain.

The rate of travel cannot be laid down by any hard and fast rules. Conditions which will govern the rate of travel are visibility, obstructions to travel, condition of team (taking the weakest member of the team as the stand-

ard), amount of oxygen in the bottles, and anything that may be applicable to local conditions.

Travelling on ladders "under oxygen" should be undertaken only after the value of this work in relation to the hazards involved has been carefully considered.

Fastening Team Members Together

When travelling in strange territory or in atmospheres where visibility is limited or may become so, the members of the rescue team should be fastened together by means of a link-line. In emergencies, where the link line is liable to become an additional hazard, e.g. when carrying a stretcher or patient, and as long as there is some other means of keeping team members together, the link lines may be disconnected.

Definition and Description of "Lines" Used

The following terms have been standardized for mine rescue work.

Guide-line.—The guide-line consists of a line or telephone cable stretched from the fresh air base or shaft station to the working-face in such a manner that a team may guide itself through strange territory or dense atmospheres.

Link-Line.—The link-line is a 5 ft. length of 3/8" polypropylene rope with a heavy snap spliced to each end. "D" rings to which these snaps are to be fastened are built into the special lamp belts used by Ontario Mine Rescue Team members while wearing Drager BG 174 or any other type of breathing apparatus.

Passing Team Through Ventilation or Fire Doors

A team captain should make certain that all doors are left as found unless he receives definite instructions, preferably in writing, to the contrary.

To ensure that this is done the following procedure should be adhered to:

1. On coming to a closed door the captain should halt the team.

2. The captain should open the door and remain at it.

3. Still standing at the door, the captain should advance the team through the door until the last man is through.

4. When the last man is through the captain should halt the team.

5. The captain should then close the door, take his place at the head of the team, and give the signal to advance.

When wearing link-lines, the captain will disconnect his snap and hand it to no. 2 man. Pass the team through the door in the normal manner and re-connect snap before giving the signal to move off.

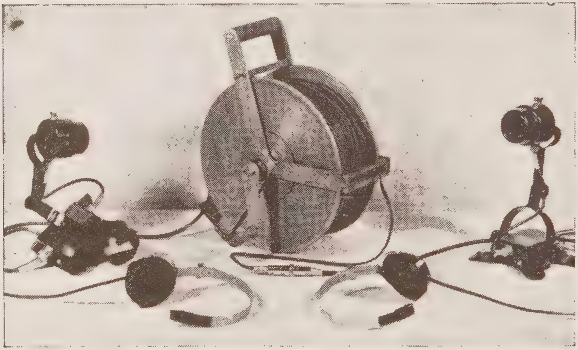

Fig. 69—Complete Assembly of Batteryless Telephone and Reel.

When travelling in smoky atmospheres the mine rescue team members will find it advantageous to carry their electric cap lamps in their hands.

If the atmosphere is very dense it is better to have the lamp as near the rail of the track as possible, letting

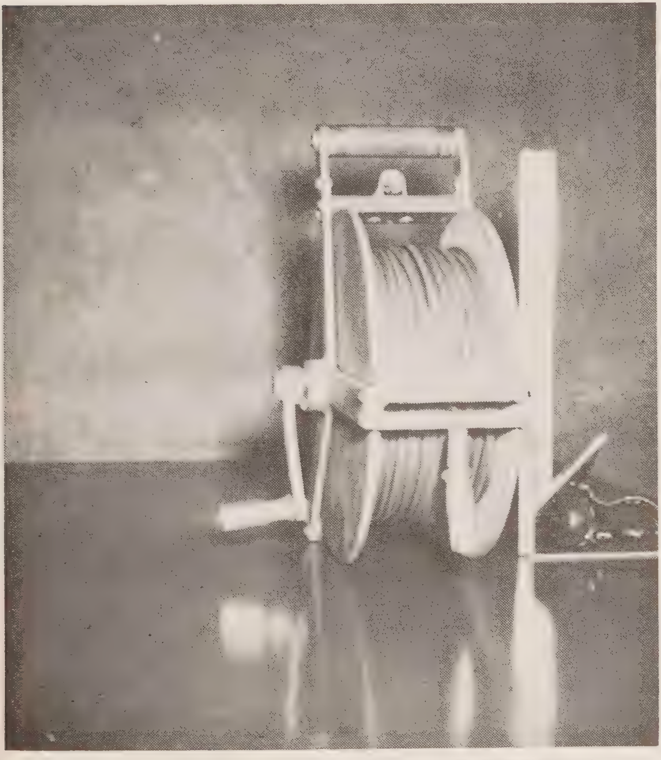

Fig. 70—Front View showing Size of Telephone Reel.

the lamp hang by its cord so that the light is directed on to the top of the rail.

There is a disadvantage in carrying the light on the hat, as the reflection cast back by the solid particles of smoke close to the man's face tends to blind him.

Methods of Communication

Communication Between Fresh Air Base and Team

It is essential that means of communication be established between teams working ahead of a fresh air base and the base itself. When wearing breathing apparatus, communication may be carried on by telephone, either batteryless or battery-powered. This is the ideal method of

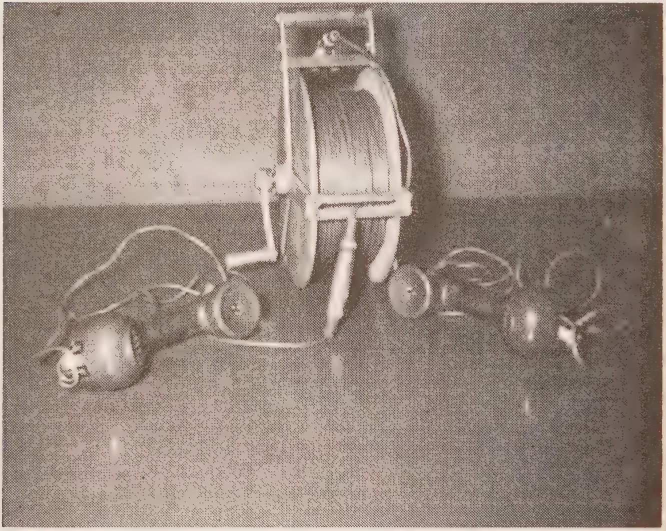

Fig. 71—Battery-Powered Telephones and Reel.

communication as the men in charge of operations are in constant touch with the advance teams. The assembly and parts of such a system are shown in Fig. 69, 70, 71, 72, 73.

Communication Between Team Members

Team members can talk with one another, but it is essential that conversation be limited. Whistle signals should be used for all team movements as follows:—

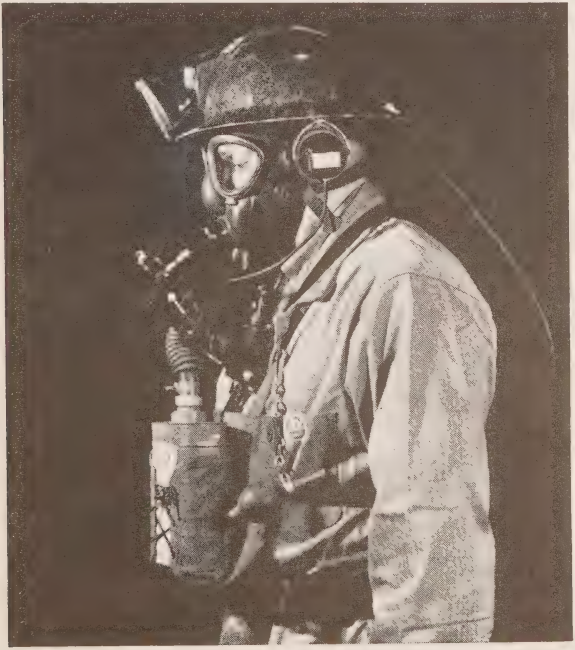

Fig. 72—Man wearing Type N Mask and Batteryless Chest-set Telephone

Code of Signals

1—Stop. 2—Advance. 3—Turn around. 4—Attention or Emergency.

Signals given by mechanical means, such as whistles or horns, by the team captain to the team are repeated by the vice-captain.

Travelling With the Telephone

In order to minimize confusion and inconvenience when travelling with the mine rescue telephone, these procedures should be followed:—

1. No. 2 man should carry the reel currently being used, and preferably in his left hand, to avoid striking his leg with the crank as it unwinds.

2. If extra reels are necessary they may be carried by no's. 3, 4, 5.

3. As the team captain inspects the team, the no. 2 man should follow him with the reel.

4. Standard procedure will be followed at ventilation doors, and the captain should hold the reel as the remainder of the team is moving through the door. Be very careful to see that the door in closing does not pinch the wire.

5. As the captain takes his place again at the head of the team, he will hand the reel back to the no. 2 man.

6. In retreating under normal conditions, the telephone wire should be re-wound by no. 2 man, but if more than one reel has been used, he may exchange places with another man for the re-winding of subsequent reels.

7. If the time element is important, the wire may be gathered up rather than be re-wound on the reel. In this case the number 5 man should coil some 150-200 feet of wire on his arm, then numbers 4 and 3 could do likewise in turn. The wire would then be wound on the reel at the fresh air base.

8. In extreme emergencies under actual conditions, e.g. where it becomes necessary to evacuate either a team member or a victim with all possible speed, the telephone reel should be disconnected and abandoned.

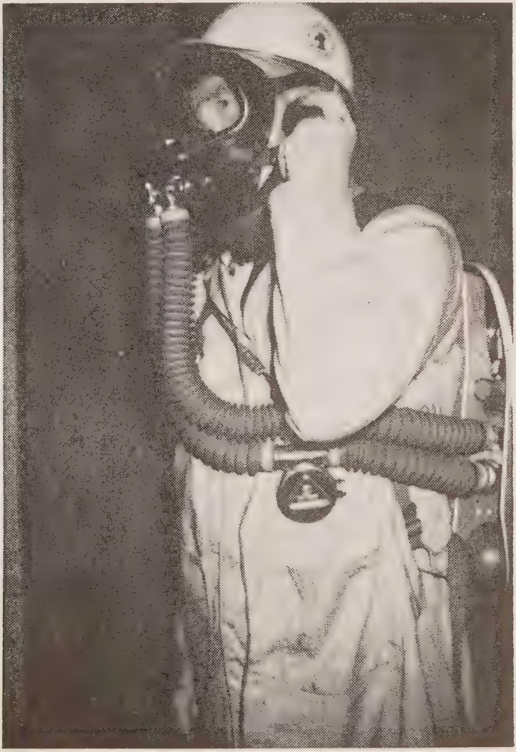

Fig. 73—Man wearing Drager Breathing apparatus and using telephone hand set.

Marking Route of Travel

It is necessary that the route of travel be marked in such a manner that it may assist the team to find its way back to the fresh air base and show a team that is following the route that has been taken.

A broad arrow chalked on the side of the travelway, pointing toward the fresh air base or level station, is a recognized standard way of marking a route. When more than one rescue team is operating at a time, the team number should be written above the arrow, e.g. $\xrightarrow{\quad 3 \quad}$

Routes of travel should be clearly marked at all intersections, but are not necessary in travelways with no branches.

At the end of the travel the team captain should mark the wall with heavy vertical lines and place near this mark the time, the date, and his initials. This is not necessary however when teams are retreating from the face of a drift etc., where there is no alternative.

When retreating, the team captain should cancel the markings he made on the ingoing trip with a broad "X," thereby indicating that the team has travelled that route, but has retreated.

When visibility is at zero, dependence must be placed on the sense of touch. If the team is to travel in drifts or crosscuts where track is laid, it is simple to follow the track by sliding one foot along a rail. When a switch is reached it should always be left so that it makes a continuous track to the fresh air base which can be followed by a retreating team. If no track exists, much time can be saved by having several teams in apparatus install a guide-line to the working-face, each team advancing it in turn. As each team completes the installation of its allotted section of guide-line, the captain should mark the place where the line ends with an obstacle across the drift. This

may be a small cairn, boards, timber, or anything available which can be identified by touch. On reaching the fresh air base the team captain should describe such obstruction clearly in his report.

The habit of marking the route of travel with chalk at all times should be formed when the team is in training. It should be done even when using guide- and telephone-lines, as loose rock may fall and cut such lines.

Barricades

General Considerations

When miners have been trapped by fire in the mine they should not rush aimlessly around, but should immediately take action to protect themselves.

When the way of escape is cut off but the local atmosphere is free of contaminating gases, consideration should be given to the building of a barricade or bulkhead. Tools, timber, canvas, water, dinner-buckets, and anything else that might be useful should be collected.

A suitable place should be chosen for the erection of the barricade and its construction started without delay, as the deadly gases often travel quickly. The time required to build an efficient barricade will vary from 30 minutes to 2 hours, depending on conditions.

To provide a maximum quantity of air, as much territory as possible in drifts and crosscuts should be included in the barricaded area, regardless of the number of men in the party.

Before constructing barricades it is necessary to make sure that there are no other openings or connections with other workings through which gases can enter, also that the crosscut or drift is not in broken ground through which gas can seep.

After the barricade has been built the men should keep as quiet as possible, because a man uses several times as much oxygen when he exerts himself as when he keeps absolutely quiet. However, somebody should walk around occasionally to mix the air. All the men should not congregate in one place.

All open-flame lamps, should be extinguished to conserve oxygen. Electric batteries should not be used needlessly. Smoking should be prohibited.

Food and water should be conserved.

A sign should be placed outside any stopping stating

Fig. 74—Lumber barricade (showing door removed)

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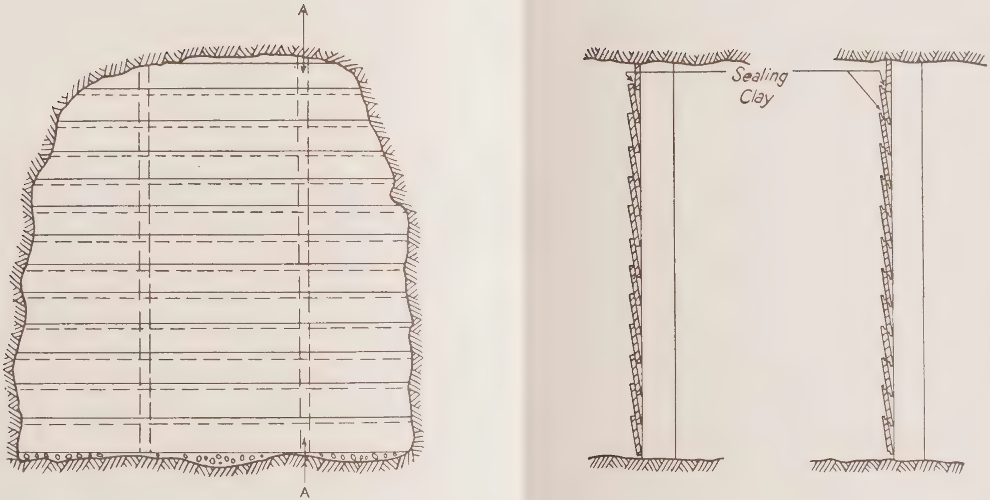

Fig. 75—Temporary Barricade of Lumber

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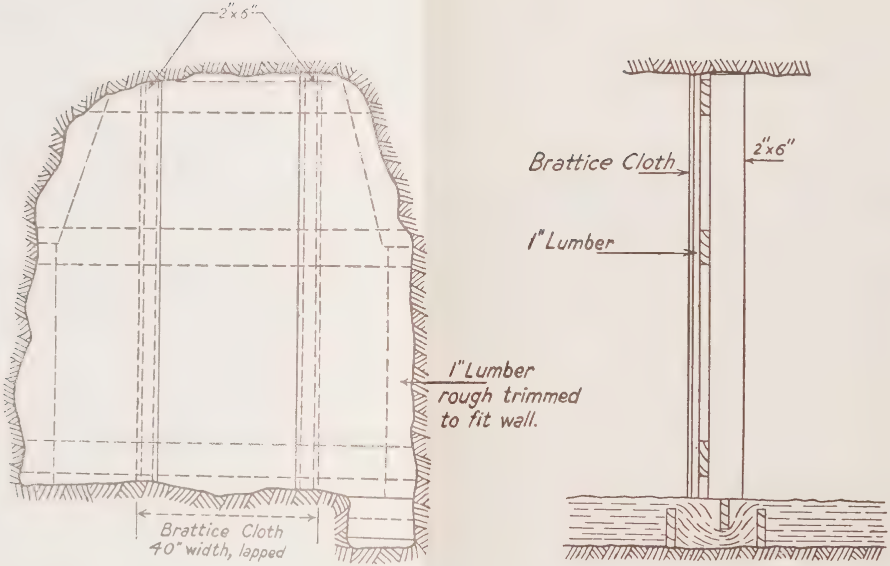

Fig. 76—Temporary Barricade of Brattice Cloth.

Note the overlapping of the edges and the method of damming the ditch.

that there are men behind the barricade and giving the number. Badge numbers would also be advisable.

If possible, barricades or bulkheads should be erected in such a location that a valve in the compressed-air line will be inside the barricade. The valve should be opened occasionally to furnish additional air. A check should be made, however, to make certain that poisonous gases are not entering the barricaded region through a break in the compressed-air line.

If circumstances permit and materials are readily available, a second barricade should be erected at a distance of 25 to 50 feet inside the first to provide an air-lock.

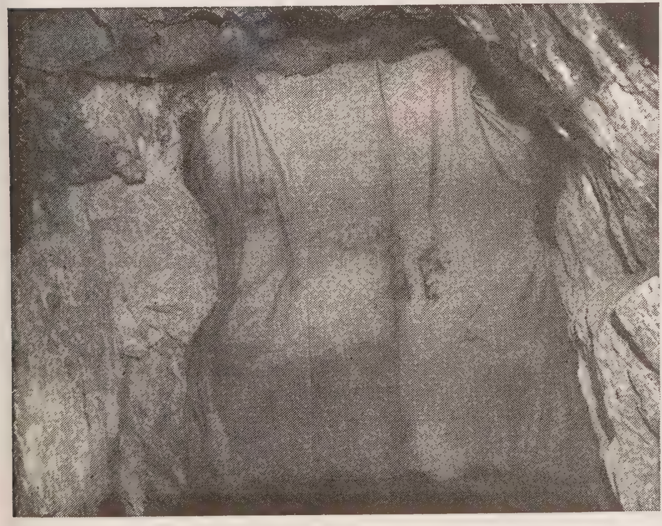

Fig. 77—Brattice cloth barricade

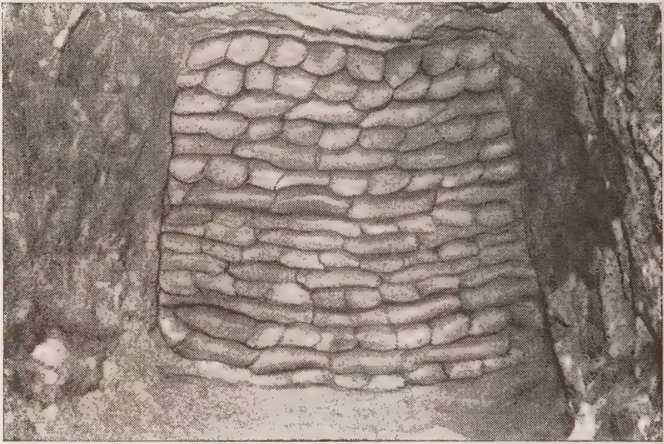

Fig. 78—Sand-bag barricade (completed).

Methods of Construction (Figs. 74 to 80)

Barricades vary in construction, depending on the time and materials available and the requirements of the structure.

Barricades constructed by men whose escape has been cut off by noxious gases may be built of any material such as rock, lumber, canvas, or clothing which can be found in the area.

If large pieces of rock are used for the barricade, two walls about 2 or 3 feet apart should be built and the space between should be filled with fine materials, preferably mud. The stoppings must be as air-tight as possible. It is more difficult to make board stoppings air-tight than those of dirt, rock, soft clay, or mud. All chinks and holes in the barricade should be stopped with clay, rags, clothes, or similar material. If a piece of pipe

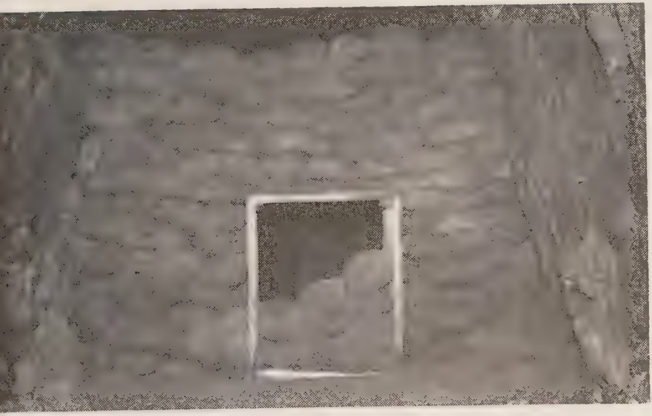

Fig. 79—Sand-bag barricade, partially completed showing travelway

Fig. 80—Method of piling bags.

is available it should be placed through the stopping or barricade and plugged at the inner end for use as a vent for testing for gas. A barricade may be constructed of lumber with the cracks or openings packed with canvas, clothing, paper, or any other suitable material.

Barricades built by mine rescue teams for the control of ventilation may be either temporary structures or permanent stoppings to seal a fire area.

Temporary barricades may be built of material such as sandbags, brattice cloth, filter cloth, lumber, blankets, or sheets of building-board. At least two should be built at each site, usually 25 or 30 feet apart, to form an airlock. They usually require from 30 minutes to an hour each to build including the erection and the claying of all joints.

The most common type is built of lumber or shiplap (Fig. 74). A sufficient number of posts are stood in an upright position. Starting at the top, the first board is nailed across the posts, fitted approximately to the contour of the roof, and the second board is laid with an overlap of about 2 inches. This overlapping is continued until the drift is closed. Clay is packed around the sides and in each trough formed by the overlapping of the boards. Care should be taken that all joints are well sealed.

A lumber barricade may be erected with prefabricated doors and door frames of proper size to suit the mine travelway. Such a barricade enables the rescue team to pass in or out of the fire area easily and quickly. This type of barricade is particularly suitable in advancing a fresh air base. The door frame is held in place and the openings around it are boarded up and sealed with clay. The door should be fitted with a suitable latch so it can be opened from either side.

A sand-bag barricade has several advantages when used as a temporary stopping. It can be erected when the

smoke is fairly dense, as there are no nails to drive or axes to swing. In many cases the bags can be filled on surface, thus reducing the amount of work required from the team in unfavourable conditions underground. The sand-bag barricade can be more quickly erected and can be made much stronger and more air-tight than either brattice cloth or lumber.

If there is a possibility that water might build up behind a barricade, a suitable water trap should be constructed. Such a trap may be made by connecting two 90 deg., 4″ pipe elbows to a 1 foot length of pipe to form a "U". This should be installed in the ditch or low spot under the barricade, and filled with water. This will prevent air movement through the pipe, but will allow any future accumulation of water to pass. (See fig. 76)

Fig. 78 shows a completed sand-bag barricade, Fig. 79 shows a partially completed barricade with a frame for a travelway, and Fig. 80 shows one method of piling bags, but variations may be used, depending on available supplies and time.

Permanent barricades, seals or stoppings are constructed to seal a fire area permanently. They may be built of brick, concrete, stone, or tile. Pressure-resisting, permanent barricades should conform to the rules of the Mining Act of Ontario.

Refuge Stations and Barricaded Areas

Refuge Stations are becoming more numerous in Ontario mines, and in many cases they are used daily as lunch rooms. This keeps the workmen familiar with the location in the event of an underground fire.

A refuge station should be excavated from the solid rock, and be equipped with comfortable benches, compressed air and water lines, electricity for light and heat, and telephone service to surface. The concrete door frame

should contain a steel door, opening outwards, capable of being sealed air-tightly with clay or plastic material. Some means must be provided in the door to allow the escape of air pressure in the event the compressed air valve within the sealed area must be opened. A means of sealing this opening must be provided on the inside of the door.

Refuge Stations are advisable in the vicinity of winze collars, where they may be readily converted to Advanced Fresh Air Bases in the event of a fire in a location served by the winze.

The cubic content of a perfectly-sealed refuge station, without any additional supply of fresh air from compressed-air lines, determines the number of men that can occupy it, and the length of time they can safely remain. In breathing, the men consume oxygen from the air and give off an almost equal amount of carbon dioxide. When the proportion of carbon dioxide in the air of the enclosed space reaches 8 per cent., the men breathe heavily and are at the point of complete exhaustion. Men have lived for considerable periods in an atmosphere in which a carbide light would not burn, thus indicating that the air contained less than 13 per cent. of oxygen. A man at rest consumes less oxygen and gives off less carbon dioxide than when working. In a confined space, however, the air will finally become unfit to sustain life. Experiments have shown that a man in a confined space requires approximately one cubic yard of air per hour. At the end of an hour this cubic yard of air will contain about 14 per cent. of oxygen and 5 per cent. of carbon dioxide. A flame lamp or match will not burn, and a carbide light will be almost extinguished. On the basis of one cubic yard of air per hour, and enclosed space 10 feet wide, 10 feet high, and 10 feet long (1,000 cubic feet or 37 cubic yards) will support one man for 37 hours before he begins to suffer through lack of breathable air. This minimum allowance of one cubic

yard per hour per man, however, does not provide for loss of oxygen through absorption by the ore or timber in the enclosed space or for the contamination of the air by noxious gases from the ore or rock.

In one metal mine the air in a barricaded drift 250 feet long, 6 feet high, and 6 feet wide (9,000 cubic feet) kept 29 men alive for 36 hours. In the same mine another drift 130 feet long, 7 feet high, and 7 feet wide (6,500 cubic feet) contained sufficient air to support 6 out of 8 men for 50 hours; the other 2 men were found dead. The 6 who were alive were all unconscious, but were revived.

The value of barricades cannot be too strongly emphasized. They have been the means of saving hundreds of lives in coal and metal mines. Many additional lives may be saved if men are properly instructed in their use.

Opening a Barricade

Before opening a barricade behind which men have taken refuge, the air outside should be made respirable if possible.

However if delay in clearing the atmosphere outside the barricade should endanger the lives of the trapped men, an air lock should be constructed as close to the mens' barricade as possible, and the men removed with suitable apparatus.

A BARRICADE WHICH HAS BEEN ERECTED TO SEAL OFF A FIRE SHOULD NOT BE UNSEALED UNLESS THE DIRECTOR OF OPERATIONS HAS GIVEN DEFINITE ORDERS TO DO SO.

Questions on Chapter VII

1. What are the three main objects of rescue and recovery operations?

2. What is the preferred number of men required for rescue and recovery teams?

3. What are the time limits for rescue team trips?

4. Describe a fresh air base, its location, etc.

5. Describe the main essentials of a fresh air base.

6. What are the duties of the captain and members of a rescue team?

7. What are the responsibilities of a mine rescue team guide?

8. Describe the order of travel of a rescue team.

9. How are team members fastened together?

10. Describe the method of passing a team through closed fire doors.

11. When and why are lights carried in the hand by team members?

12. Define "link-line," and "guide-line."

13. What method of communication is used between a team and the fresh air base?

14. Give the standard code of whistle signals as used by mine rescue teams.

15. Describe the method of marking the route of travel.

16. Describe the general requirements in locating barricades for refuge purposes.

17. Describe recommended procedures for men behind barricades.

18. Describe methods of construction of the following:

(a) life-saving barricades;

(b) barricades erected by mine rescue teams;

(c) permanent barricades.

19. What is the life-sustaining capacity of a barricaded area 10 feet wide, 10 feet high and 10 feet long?

20. What precautions should be taken before opening a barricade behind which men have taken refuge?

21. On what authority should a barricade erected to seal a mine fire be opened?

22. What procedure should be followed by a mine rescue team immediately after entering contaminated air?

23. What precaution must be taken before removing breathing apparatus while underground?

24. Where, when and how should the briefing of a mine rescue team be carried out?

CHAPTER VIII

Underground Fires

Causes of Metal-Mine Fires:

Most fires occurring underground are caused by one of the following:

(a) Electricity in its many forms. Battery locomotives, power cables, trolley wires, motors, electric heaters and even electric light bulbs are some examples of mine fires caused by the use or misuse of electricity.

(b) Man-made, whether deliberate or accidental. Welding and burning operations, smoking, blasting, and the setting of fires for warmth are among many of the causes.

(c) Spontaneous combustion of sulphide ores or backfill, particularly if ventilation is not sufficient to carry off the heat of oxidation.

(d) Friction, causing overheating of brake bands or clutches on slushers: transmission gear boxes; V-belt drives; and to a limited extent, conveyor belts.

Classification of Fires

Almost all common types of fires can be classified as A, B or C:—

Class A—Fires in timber, refuse, or organic solids.

Class B—Fires of flammable liquids, such as oil, tar, solvents.

Class C—Fires involving the presence of electric current, whether or not electricity was the direct cause.

Control of Fires

It is well known that most large fires start as small ones, and can usually be extinguished easily if discovered in the

early stages and if suitable equipment or material is readily available. This applies to fires both on surface and underground.

Portable Fire Extinguishers—(Fig. 81)

Fire extinguishers of types suitable for the hazard that might be expected locally, and when properly maintained and used, provide excellent protection against a minor fire becoming one of major proportions.

(a) *Water-Type Extinguishers.* This group includes the 5-gallon pump tank, 2½ gallon soda-acid, and the 2½ gallon stored pressure. Larger sizes of this type of extinguisher include the 150 gallon Fog-O-Car, mounted on wheels and pressurized by compressed air, nitrogen or carbon dioxide. WATER TYPE EXTINGUISHERS ARE EFFECTIVE AND SAFE ON CLASS A FIRES *ONLY.* THEY MUST NOT BE USED ON CLASS C FIRES.

(b) *Foam Extinguishers.* Effective and safe on Class A and B fires, and must not be used on Class C fires. They are commonly available in 2½ gallon, or larger wheel-mounted types. The extinguishing agent is chemical foam which blankets or smothers the fire by excluding oxygen.

(c) *Carbon Dioxide Extinguishers.* Safe to use on Class A, B and C fires, but only moderately effective on Class A, and are recommended for Class B and C. They are available in sizes of 2, 5, 10, 15, 20 and 25 lbs., and in larger wheel-mounted types. The extinguishing agent is liquid CO_2 while in the extinguisher, but is discharged as snow which vaporizes quickly to CO_2 gas, and extinguishes fires primarily by excluding or diluting oxygen.

(d) *Dry Chemical Extinguishers.* Like the carbon dioxide extinguisher, these are safe on Class A, B and C, and are highly recommended for Class B and C fires.

The extinguishing agent is basically sodium-bicarbonate or potassium bicarbonate in dry powdery form, to which

KNOW YOUR FIRE EXTINGUISHERS

KNOW YOUR FIRE EXTINGUISHERS	WATER TYPE				CARBON DIOXIDE	DRY CHEMICAL	MULTI-PURPOSE
	STORED PRESSURE	SODA ACID	WATER PUMP TANK	FOAM	CO2	DRY CHEMICAL	DRY CHEMICAL
CLASS A FIRES WOOD, PAPER TRASH HAVING GLOWING EMBERS (A: ORDINARY COMBUSTIBLES)	YES	YES	YES	YES	NO (BUT WILL CONTROL SMALL SURFACE FIRES)	NO (BUT WILL CONTROL SMALL SURFACE FIRES)	YES
CLASS ■ FIRES FLAMMABLE LIQUIDS GASOLINE, OIL, PAINTS, GREASE, ETC (B)	NO	NO	NO	YES	YES	YES	YES
CLASS C FIRES ELECTRICAL EQUIPMENT (C: EQUIPMENT)	NO	NO	NO	NO	YES	YES	YES
USUAL OPERATION	UPRIGHT SQUEEZE HANDLE OR TURN VALVE	TURN UPSIDE DOWN	UPRIGHT AND PUMP HANDLE	TURN UPSIDE DOWN	SQUEEZE RELEASE	RUPTURE CARTRIDGE SQUEEZE NOZZLE TO RELEASE	RUPTURE CARTRIDGE SQUEEZE NOZZLE TO RELEASE
RANGE	30' - 40'	30' - 40'	30' - 40'	30' - 40'	3' - 8'	5' - 20'	17' - 25'
SERVICING	CHECK AIR PRESSURE	DISCHARGE ANNUALLY AND RECHARGE	CHECK PUMP AND FILL WITH WATER ANNUALLY	DISCHARGE ANNUALLY AND RECHARGE	WEIGH SEMI-ANNUALLY	WEIGH GAS CARTRIDGE AND CHECK CONDITION OF DRY POWDER	WEIGH GAS CARTRIDGE AND CHECK CONDITION OF DRY POWDER

Fig. 81—"Know Your Fire Extinguishers"

has been added a component to repel moisture and maintain free-flow. The powder is expelled under pressure, produced either by compressed air stored in the extinguisher, or by puncturing a small CO_2 cartridge attached to or confined within the extinguisher. As the ejected powder granules become warmed by the heat of the fire, each tiny particle produces CO_2 gas, which acts by excluding or reducing oxygen within or surrounding the fire.

Water Fog is a modern fire-fighting device, useful and safe on Class A and B fires, both on surface and underground. Water fog is composed of millions of fine particles of water expelled through a special high-pressure nozzle.

As the super-fine spray hits the fire, the heat is reduced from as much as 1,800 to 200 degrees F. and the water is turned to steam, cutting off the oxygen and extinguishing the fire.

Water fog produced by a proper "impinging-type" nozzle is very useful as a heat barrier to rescue teams advancing towards the fire. Water damage is also greatly reduced over that caused by large quantities of water through standard nozzles.

High-Expansion Foam. High-expansion Foam is created by spraying a mixture of concentrated detergent and water over a knitted nylon netting with ⅛ inch holes spaced ⅛ inch apart. Air from a blower fan is directed against the netting, forcing the liquid mixture through the mesh, causing bubbles to form on the rear side. These bubbles can be generated in sufficient quantity to completely fill or plug the drift or travelway. The foam plug is forced to move forward by the velocity of the air, with a continuing process of bubble formation taking place.

The use of high-expansion foam shows promise as a means of extinguishing certain types of fires in metal mines. It may also be used as a means of controlling or eliminat-

ing excessive heat, to permit rescue teams to advance through the foam to gain closer access to the fire.

High-Expansion-Foam Generator—(Fig. 82)

Ontario Mine Rescue Stations are equipped with diesel-powered, high-expansion foam generators capable of producing 6000 cu. ft. of high-expansion foam per minute with a ratio of 1000 parts of air to one of water.

The unit uses 45 gallons of water and 0.7 gallons of foam concentrate per minute.

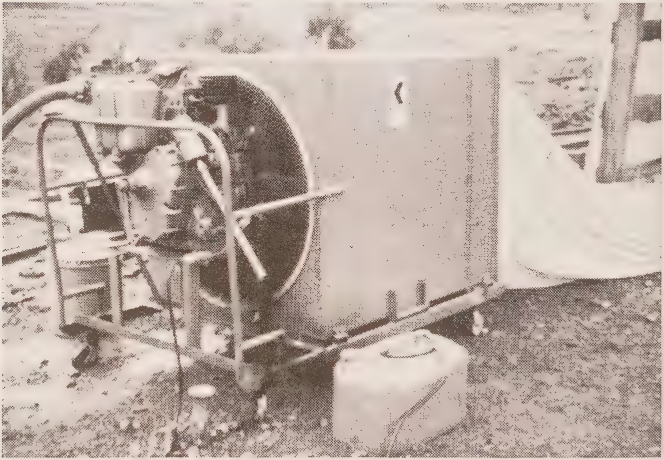

Fig. 82—High-Expansion-Foam Generator

The generator consists of a fan mounted on the crankshaft of a one-cylinder diesel engine, a plenum chamber, a bank of four spray nozzles and a knitted nylon net on which the foam is formed. Water is fed into the unit through a 1½ inch hose, and an "in-line" proportioner

draws foam concentrate through a metering orifice into the water stream.

A mixture of foam concentrate and water is sprayed at about 12 p.s.i. onto the nylon net through the nozzles, creating a constant spray pattern for even wetting of the net. The foam created by air passing through the netting is delivered through tubing.

Operation of the Foam Generator

The water hose is connected to a hydrant or pipe valve in a line capable of supplying 45 gallons of water per minute, at a minimum pressure of 50 p.s.i. The water supply should be reasonably free from dirt or scale which might clog the inlet strainer.

The water pressure gauge reading should be held constant even though the supply pressure varies. Should the pressure reading fall below the mark on the gauge dial, the pressure is too low, or the inlet strainer is plugged with dirt.

The stainless steel pick-up tube is fitted with a fine screen to prevent the entrance of foreign material into the metering orifice.

Procedure for Using the Foam Generator Underground—(Fig. 83).

1. Set up the generator adjacent to a previously-prepared barricade with an opening at least 3 by 5 feet, or to a doorway in a drift or roadway.
2. Attach one end of the desired discharge tubing to the zippered connection on the generator. Carry the other end through the doorway and fasten or brace it to the door frame.
3. Open the valve on the water supply line and flush the line until the water runs clear. Rusty water makes poor foam.

4. Connect the $1\frac{1}{2}$ inch water hose to the unit and pressurize the line up to the inlet water control valve.
5. Start the engine and accelerate until the air-flow meter indicates within the green area. The engine may require

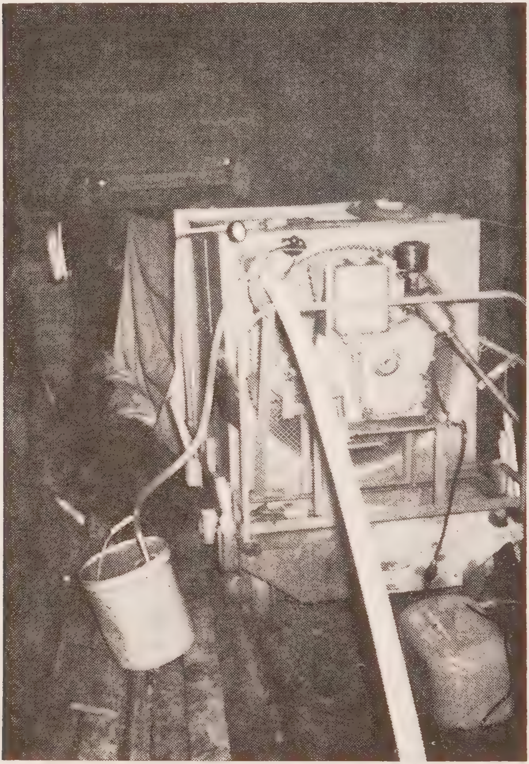

Fig. 83—Hi-Ex Foam Generator set up Underground

further adjustment as the concentrate is applied on the netting.

6. Open the inlet water control valve until the pressure gauge reaches the marked point.
7. Insert the detergent pick-up tube into the foam concentrate container.

After use, the discharge tube should be cleared of residual foam. A convenient way to clear the tube is to have two men, one on either side, pass a rope under the tube, raise it slightly and walk its entire length from the generator to the open end while running the fan at high speed.

The tube should be hung up to dry thoroughly after use and rolled so that the guide rings are on the inner end of the roll and the zipper slide on the top. This will allow the tube to be rolled out correctly by fan pressure the next time the unit is used.

The proportioner and pickup tube should be flushed with clear water after use. Check the screen on the pickup tube for cleanliness, run water through the nozzles to be sure they are not clogged, and check the screen at the hose inlet. Foam detergent is corrosive with metal.

Fire Attack with Hi-Ex Foam

The tremendous volume of foam being discharged into an area seals it and prevents fresh air from reaching the base of the fire. Once the fire has been reached, the foam continues to exclude fresh air and holds the steam and oxygen-deficient atmosphere around the fire.

When the water film of the bubble wall approaches a fire, radiant heat vaporizes the water in the foam front. The one part water in 1000 parts air expands 1700 times in forming steam. The resulting steam-air mixture has an oxygen content of around 7.5%, well below the level required to support combustion. Large volumes of steam thus

formed displace additional hot gases and tend to create inert areas above the fire and limit its spread.

Bubbles cannot exist in contact with a dry surface. As a result Hi-Ex foam wets down those areas where the water is needed. The surface tension of the water in the foam is quite low and penetration is thus deeper than with equal volumes of plain water.

Cooling and extinguishing are accomplished by a high steam atmosphere. The generator should be operated to produce foam at as high a rate as possible.

After the burning material has been covered, the foam covering should be maintained to cool the hot material.

Travelling Through High-Expansion Foam

Persons wearing self-contained oxygen or air-breathing apparatus may travel safely through the foam, even though submerged in it. Care should be taken that all team members are fastened closely together, and travel should be along a track rail, or a wall, where it is known there are no openings or obstructions underfoot.

Do not enter foam wearing a canister type gas mask, as the filters will become saturated and completely close off the passage of air.

WHEN KNOWN FRESH AIR HAS BEEN USED in producing foam, it is possible to pass through, and to breathe the foam while not using any breathing apparatus. Discomfort is reduced by wearing a handkerchief or piece of folded cotton across the nose and mouth. Eyes must be kept closed or protected by goggles. THIS PRACTICE SHOULD BE FOLLOWED ONLY FOR THE PURPOSE OF SAVING LIFE.

Questions on Chapter VIII

1. Name and describe the four main causes of metal mine fires.

2. Define Class A, B, and C fires.

3. Name the four types of portable fire extinguishers.

4. What is "High Expansion Foam"?

5. Describe the six steps necessary preparatory to using the Foam Generator underground.

6. Under what conditions only, is travelling through High Expansion Foam to be permitted?

CHAPTER IX

Medical Requirements

Method for Determination by a Physician of the Fitness of Men for the Wearing of Breathing-apparatus Just Prior to Use in Service or Initial Training

The Medical Report form for an applicant for training in Mine Rescue and Recovery Operations consists of two sections; one is retained by the employer and one is kept at the Mine Rescue Station. One side of the first portion (Fig. 84 is filled in by the employer before the applicant is sent to the examining physician, and is retained by the employer after the reverse side (Fig. 85) has been completed by the physician. One side of the other portion (Fig. 86) which is a duplicate of the side shown in Fig. 85, is filled in by the employer before the applicant is sent to the examining physician, and is kept at the Mine Rescue Station after its reverse side (Fig. 87) has been signed and dated by the physician.

Discussion of Medical Requirements

Miners vary greatly in physique and no definite standard can be laid down as to height, weight or chest measurement. Much must be left to the examining physician. It is, however, emphasized that the applicant must be of average or better than average physique.

Training should not be given to men under 21 years of age or over 45. Men under 21 years of age or over 50 should not actively engage in rescue and recovery work which involves their wearing oxygen breathing-apparatus.

The following chart will assist in determining the applicant's physique:—

CANADIAN AVERAGE WEIGHTS FOR HEIGHT AND AGE (MEN)

(In ordinary indoor clothing, without shoes)

Height in Feet - Inches		18-19 years	20-24 years	25-29 years	30-34 years	35-44 years	45-54 years
4′	11″	116	121	128	134	135	127
5′	0″	119	124	132	138	139	132
	1″	122	127	135	141	142	136
	2″	125	131	139	145	146	141
	3″	128	134	142	148	150	146
	4″	131	138	146	152	153	150
	5″	134	142	149	156	157	155
	6″	138	145	153	159	161	160
	7″	141	149	156	163	164	165
	8″	144	152	160	166	168	169
	9″	147	156	163	170	172	174
	10″	150	159	167	173	175	179
	11″	153	163	170	177	179	183
6′	0″	156	166	174	181	183	188
	1″	160	170	177	184	186	193
	2″	163	173	181	188	190	197
	3″	166	177	184	191	194	202

Information supplied by Department of National Health and Welfare
Ottawa, 1954

Although no definite limits can be set, experience has shown that men from 21 to 36 years of age, from 5 feet 4 inches to 5 feet 10 inches in height, and weighing from 135 to 170 pounds, are the most satisfactory.

The subject must have at least 20/40 uncorrected vision in each eye. He should be placed exactly 20 feet

ONTARIO MINISTRY OF NATURAL RESOURCES

Training in Mine Rescue and Recovery Operations

MEDICAL REPORT

Applicant for Training in Mine Rescue and Recovery Operations.

NAME____________________ NATIONALITY____________________

DATE OF BIRTH____________________ PHONE No.____________________

ADDRESS____

OCCUPATION____________________ EMPLOYMENT No.____________________

EMPLOYER____

ADDRESS____

NEXT OF KIN____________________ RELATIONSHIP____________________

ADDRESS____

Applicant should be examined by a physician before taking Mine Rescue Training.

To be filled out by employer before applicant is sent to the examining physician.

This portion to be retained by Employer

Fig. 84—First Portion of Medical Report Form (Retained by Employer).

MEDICAL REPORT

AGE________ WEIGHT__________ HEIGHT____________

VISION: Rt eye______________ Lt eye______________

HEARING: Rt ear______________ Lt ear______________

NOSE____________________________________

TEETH____________________________________

THROAT____________________________________

CHEST: Expanded______________ Deflated______________

HEART: Normal______________________________

After exercise ____________________________

After 2 min rest____________________________

BLOOD PRESSURE____________________________

ABDOMEN: Scars ____________________________

EXTREMITIES ____________________________

NERVOUS OR COMPOSED ________________________

The applicant is in my opinion of good physique and sound health and should be suitable for training in Mine Rescue Work and the wearing of breathing apparatus.

Signed____________________________

Address____________________________

Dated________________________19______

To be filled in by examining physician and retained by employer.

Fig. 85—Reverse Side of First Portion of Medical Report (Retained by Employer).

ONTARIO MINISTRY OF NATURAL RESOURCES

Training in Mine Rescue and Recovery Operations

MEDICAL REPORT

Applicant for Training in Mine Rescue and Recovery Operations..

NAME________________ NATIONALITY________________

DATE OF BIRTH________________ PHONE No.________________

ADDRESS________________________________

OCCUPATION________________ EMPLOYMENT No.________________

EMPLOYER________________________________

ADDRESS________________________________

NEXT OF KIN________________ RELATIONSHIP________________

ADDRESS________________________________

Applicant should be examined by a physician before taking Mine Rescue Training.
To be filled in by employer and given to the Mine Rescue Superintendent on completion of the physical examination of the applicant.

This portion to be retained at Mine Rescue Station

Fig. 86—Second Portion of Medical Report. Duplicate of Side shown in Fig. 84 (Retained at Mine Rescue Station).

NAME______________________________

The above named applicant has been examined by me and in my opinion should be capable of performing the duties necessary in Mine Rescue Work while wearing breathing apparatus.

Signed __________________________
Examining Physician

Address__________________________

____

Date______________________________19____

TRAINING RECORD

____________________________Mine Rescue Station

Course of Training	Date Completed
BASIC	
STANDARD	
ADVANCED	
SUPERVISORY	
REFRESHER	

____
Station Superintendent

These certificates shall be renewed at the end of one year from date thereof.

Fig 87—Reverse Side of Second Portion of Medical Report. (Retained at Mine Rescue Station).

from well-lighted test cards (Snellen's). Each eye should be tested separately, the eye not under test being excluded by holding a card before it. No pressure should be exerted nor should the excluded eye be closed. As soon as the lowest line that the subject can read has been determined, the vision should be recorded as a fraction (20/40), the numerator being the distance in feet at which the test was made—that is, 20 feet—the denominator, the number on the card opposite the last line read by the subject. A subject with less than 20/40 vision in either eye should be rejected.

The subject should have average hearing in each ear. To determine this both whisper and watch tests are used. The subjects stands 20 feet from the examiner. He closes the ear not under examination with his moistened index finger pressed firmly into the external auditory meatus. Then the examiner, facing the back of the subject, exhales and with his residual air whispers numbers, words, or sentences that should be repeated by the subject. The other ear is tested in like manner. If the subject is unable to hear at 20 feet, the examiner approaches until the subject does hear, and the distance is recorded in feet. If the distance is less than 15 feet, the subject should be rejected. A quiet room is essential. The watch test may be made with any watch that has been previously tested out on at least five persons with normal hearing, and the distance used as a standard. A loud-ticking watch, such as an Ingersoll, is preferable and, although the ticking is variable, it should be heard at about 40 inches. The number of inches at which ticking is heard, when the subject's eyes are closed and his opposite ear occluded, are taken as the numerator and the distance the watch should be heard as the denominator. This should be equivalent to 30/40, otherwise the subject should be rejected.

It is preferred that the subject have solid teeth in front,

including bicuspids, above and below. With the increased use of facepiece-type breathing apparatus, however, good-fitting dentures would not be a cause for rejection.

There should be no sores on the nose, lips, or in the mouth.

The chest should be normal in shape and size and the expansion should be 2½ inches or more. The condition of the heart and lungs should be normal. These organs should be given special attention; abnormalities in either should be cause for rejection. Schneider's cardiovasculor ratings, or a modification, should be used.

The abdomen and inguinal regions should be examined for weak scars and hernia, active or potential.

The man should have good use of both hands and both feet. The loss of two fingers on either hand does not disqualify, provided there is no interference with the functions of the thumb and remaining fingers.

In addition to being physically sound the man should be physically fit. Schneider's test, as used by the Air Service, may be used for the determination of physical fitness. A rescue man should be accustomed to hard work and capable of sustained strenuous exercise.

The Schneider tests and ratings are given in the tables below:

CARDIOVASCULAR RATINGS, SCHNEIDER

A. Reclining pulse rate		B. Pulse rate increase on standing				
		0–10 beats	11–18 beats	19–26 beats	27–34 beats	35–42 beats
rate	points	points	points	points	points	points
50–60	3	3	3	2	1	0
61–70	3	3	2	1	0	1
71–80	2	3	2	0	−1	−2
81–90	1	2	1	−1	−2	−3
91–100	0	1	0	−2	−3	−3
101–110	−1	0	−1	−3	−3	−3

G. Standing pulse rate		D. Pulse rate increase immediately after exercise				
		0–10 beats	11–20 beats	21–30 beats	31–40 beats	41–50 beats
rate	points	points	points	points	points	points
60–70	3	3	3	2	1	0
71–80	3	3	2	1	0	0
81–90	2	3	2	1	0	–1
91–100	1	2	1	0	–1	–2
101–110	1	1	0	–1	–2	–3
111–120	0	1	–1	–2	–3	–3
121–130	0	–1	–2	–3	–3	–3
131–140	1	0	–3	–3	–3	–3

E. Return of pulse rate to standing normal after exercise		F. Systolic pressure, standing compared with reclining.	
Seconds	Points	Change in mm.	Points
0–60	3	Rise of 8 or more	3
61–90	2	Rise of 2–7	2
91–120	1	No rise	1
After 120: 2–10 beats above normal	0	Fall of 2–5	0
		Fall of 6 or more	–1
After 120: 11–30 beats above normal	–1		

1. Subject reclines for 5 minutes. Heart recorded as per A. Systolic blood pressure is then taken and recorded as per F.

2. Subject stands at ease for 2 or 3 minutes, pulse recorded as per C; difference recorded as per B. Standing systolic pressure is then taken and recorded as per F.

3. Subject next steps on a chair about 18 inches high five times in 15 seconds, timed by a watch. To make this test uniform, he stands with one foot on the chair at the count "One"; this foot remains on the chair and is not brought to the floor again until after the count "Five." At each count he brings the other foot on the chair and at the count "Down" replaces it on the floor. This should be timed accurately, so that at the 15-second mark both feet are on the floor.

(a) Immediately, while the subject stands at ease, his pulse rate is counted for 15 seconds; this count is multiplied by 4 and recorded.

(b) Counting is continued in 15-second intervals for 2 minutes, record being made of the counts at 60, 90 and 120 seconds. The data from (a) will be scored by part D of the table by using the difference between this exercise pulse rate and the standing rate. The data in (b) are scored according to part E of the table. Perfect score is 18; 9 or less indicates physical unfitness.

Summary of Causes for Rejection

(a) Any difficulty in breathing.

(b) Defective eyesight.

(c) Respiratory diseases, such as tuberculosis, bronchitis (acute or chronic), or asthma.

(d) Any cardiac (heart) disorders.

(e) Nervous disorders, such as epilepsy or St. Vitus' dance, or nervous habits.

(f) Subnormal mentality.

(g) Younger than 21 years of age or over 45 years of age.

(h) Intemperance in the use of alcohol or drugs.

(i) Special idiosyncrasies, such as being subject to oxygen-deficiency syncope (fainting in low oxygen).

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